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MOBILE PROCESSING UNIT FOR PCB DECHLORINATION - COMMISSIONING TESTS

Report No 85-355-K

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ABSTRACT

The Mobile Processing Unit (MPU-1) for polychlorinated biphenyls (PCB) dechlorination in contaminated insulating oil was commmissioned using 22,000 L of PCB contaminated oil stocks. The MPU-1 reduced the PCB content of 120-7000 mg PCB/Kg oils to <2 mg PCB/kg to produce an oil suitable for use in electrical equipment. Each 1500 L batch discharged 25 L centrifuge residue, 60 mL vent condensate, 6 L degassifier condensate plus oil, 25 Kg spent Fuller's earth and 2.27 m^3 filtered nitrogen, in addition to product oil. Analysis indicates that neither oil nor any of the waste by-products contain significant amounts of severely toxic or hazardous compounds and the centrifuge residue closely matches the MOE waste oil classification 251.

Equipment modifications are required to improve the efficiency and reliability of the MPU-1 and post-treatment oil filtering and degassification are recommended for oils which are to be used in power transformers.

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EXECUTIVE SUMMARY

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In the late 1960s it was recognized that polychlorinated biphenyls (PCB) were a potential hazard to the environment and through the mechanism of bioconcentration a potential danger to human health. Since the 1960s, the major industrialized nations have moved to regulate the handling and disposal of PCB, and materials containing PCB.

Although set up to control the disposal of wastes, present PCB handling restrictions under Ontario Regulation 11/82 also apply to approximately 3 million litres of high quality, electrical insulating oil in service in Ontario Hydro. This is so because trace PCB contamination in the oil exceeds the regulatory limit of 50 mg/kg oil. The in-force regulations restrict the movement, servicing and use of electrical equipment containing contaminated oil and necessitate the segregation and monitoring of such oil removed from service.

Since 1977 Ontario Hydro Research Division has investigated: alkali metal/alkali metal reagent treatment; hydrogenolysis; wet oxidation; adsorption; and solvent extraction, among others, as possible methods for destroying PCB in contaminated insulating oil, with the result that a method based on reduction of PCB by metallic sodium was judged the most promising for use at Ontario Hydro. Further development has led to the construction of a portable, 6000 L/day oil processing system, the MPU-1, based on the sodium/PCB reaction and capable of treating all of Ontario Hydro's contaminated oil stocks over a 5 to 10 year period.

The MPU-1 was tested for approximately 6 months, during which time a total of about 22 000 L of oil with initial PCB contents in the range 50 to 7000 mg/kg was successfully decontaminated to less than detectable levels (<2 mg PCB/kg oil). Acceptable

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operating conditions for service oils with about 200 mg/kg PCB content and 100 mg/kg chlorinated benzene content were determined to be: 110°C reaction temperature; 24 minute reaction time; and a 13.5/1 sodium to chlorine molar ratio. The addition of a small amount of water (about 175 mL/1500 L oil) was observed to aid the reaction by providing free hydrogen.

Centrifuge residue, condenser condensates and vent gas were all analyzed for several priority pollutants. No dioxins (PCDD) or dibenzofurans (PCDF) were detected. None of benzene, cyclohexane, chlorinated benzenes, chlorophenol, phenol or PCB was detected at levels exceeding proposed or in-force regulations.

By following a classification procedure of proposed Ontario Regulation 309 the centrifuge residue was determined to belong to MOE waste class 251 "Waste Oils/Sludges from Petroleum Refining and Marketing".

Quantities of waste products discharged from the MPU-1 per 1500 L batch of oil processed were: 25 L centrifuge residue, 60 ml exhaust vent condensate, 25 kg spent Fuller's earth filtering material, 2.27 m^3 nitrogen and about 6 L of degassifier condensate.

The quality of service oils was not significantly affected by the MPU-1, provided that Fuller's earth filtering material was dry and fines were absent. The presence of clay fines or water in the output oil adversely affected the oil's power factor and post-treatment filtering or retreating with dry Fuller's earth was required to achieve the low power factor required of service oils.

Provided that modifications suggested in the report are addressed, the MPU-1 will meet the design target of four, 1500 L, batches of oil processed per 8 h working day.

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To Mr. J.S. Hartill
Manager, Transmission Stations
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MOBILE PROCESSING UNIT FOR PCB DECHLORINATION -
COMMISSIONING TESTS

1.0 INTRODUCTION

An estimated 8 percent of insulating oil in the Ontario Hydro system is contaminated with low levels of polychlorinated biphenyls (PCB). Approximately 3 million litres exceeds the 50 mg/kg limit defining PCB waste, and is therefore subject to storage and monitoring until such time as a government approved destruction facility is available.

As an alternative to eventual destruction of PCB contaminated oil, Ontario Hydro has developed a trailer mounted facility for the decontamination and reclamation of PCB contaminated insulating oil. Once tested and approved under pending Ontario Regulations for mobile PCB destruction facilities this mobile unit has the potential to eliminate low level PCB contamination from Ontario Hydro oil stocks over a 5-10 year period. Construction of the Mobile Processing Unit (MPU-1) for PCB oil decontamination was completed by Enervac Corporation, Cambridge, Ontario, in the fall of 1984, and the facility was set up in November 1984 for approximately 8 months of extensive performance testing at Site L-21 in Ontario Hydro's Kipling Complex, Etobicoke.

This report presents commissioning data obtained during MPU-1 testing by staff of the Chemical Research Department and assesses the practicality of the MPU-1 for field use.

2.0 EXPERIMENTAL

2.1 Set Up and Siting

MPU-1 was set up on a 11.6 m x 19.8 m (38 ft x 65 ft) test site adjacent to an existing oil storage and pumping facility approved for storage of PCB contaminated insulating oil and used by Ontario Hydro to remove and store oil from surplus transformers. The test site (Figure 1) contained the MPU-1 trailer, with

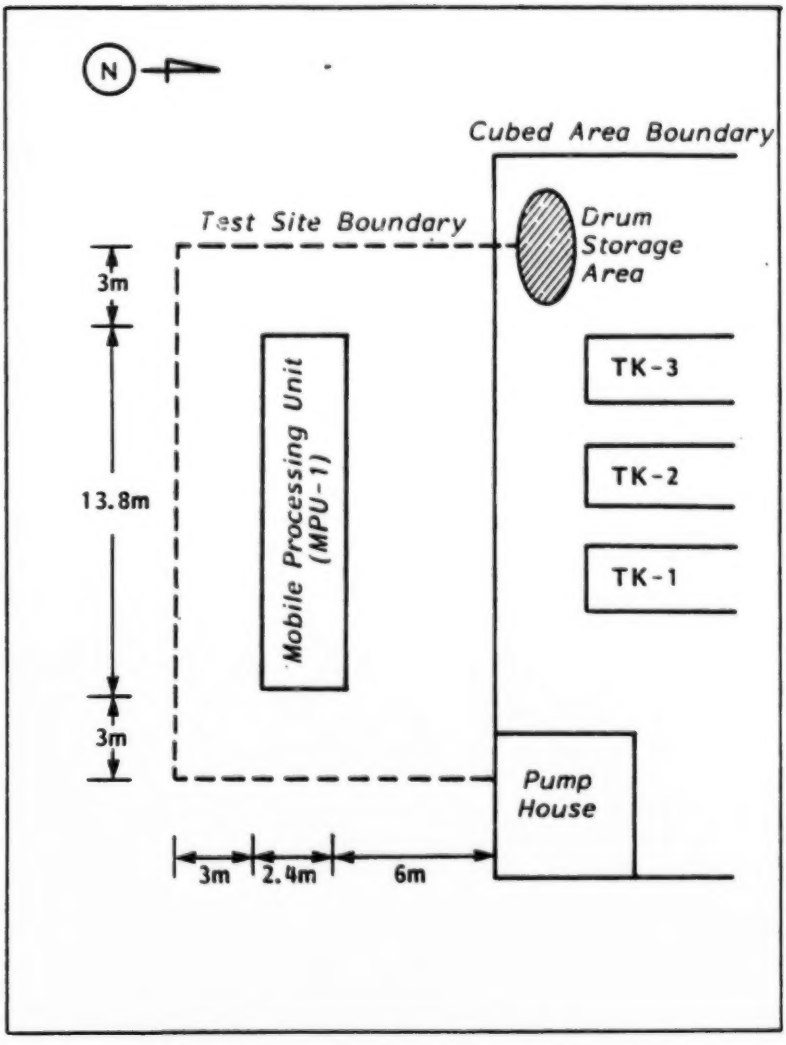

FIGURE 1
MPU-1 COMMISSIONING TEST SITE (SITE L-21)

a 3 m (10 ft) working space on three sides of the unit, and a 6.1 m (20 ft) working space between the trailer and the curb of the concrete containment basin of the oil storage and pumping facility. Flexible hoses designed for oil handling were used to connect the MPU-1 to a source of contaminated oil and oils from the following sources were used to obtain the desired PCB concentration for each test.

(1) Horizontal tank TK-1, site L-21 (7000 mg PCB/kg oil)
(2) Horizontal tank TK-2, site L-21 (<50 mg PCB/kg oil)
(3) Horizontal tank TK-3, site L-21 (700 mg PCB/kg oil)
(4) Drums, site L-21 (120 mg PCB/kg oil)
(5) Drums of new M-104 M-79 insulating oil (PCB free)

2.2 Processing

During the four month period following siting (Winter, 1984-85) preliminary tests were carried out using PCB-free oil as feed, to ensure satisfactory plant unit operations. Treatment of PCB contaminated oil by the MPU-1 commenced on a research basis on March 25, 1985 and ended on July 9, 1985. During this period approximately 3280 L of 120 mg PCB/Kg oil, 15 500 L of 700 mg PCB/Kg oil and 3000 L of 7000 mg PCB/Kg oil were processed.

Oil processing steps are described in Appendix 1, with deviations as noted in the results section. In summary, the standard oil processing procedure was as follows:

(1) Input contaminated oil.
(2) Pre-heat oil to 85°C.
(3) Degassify oil to < 100 mg/kg water content.
(4) Heat oil to 110-120°C reaction temperature.
(5) Inject sodium dispersion into the oil.
(6) Mix the oil and dispersion while sodium reacts with PCB and other reactive components.
(7) Add limited water to assist PCB/sodium reaction and react with residual sodium.
(8) Analyse oil for PCB to confirm destruction.
(9) Centrifuge output oil to remove solids.
(10) Pass output oil through an activated clay filter to improve electrical characteristics.

Decontaminated oil was output to horizontal tank TK-2 and all centrifuged or filtered solids and trapped condensates were collected in drums and stored on the L-21 pad area.

2.3 Materials Collection and Analysis

Samples of exhaust gas emissions, process oils, centrifuge residue, exhaust system condensates and Fuller's earth filter

material were collected as required during the research tests and analysed for priority pollutants. A description of the sampling and analysis methods is given in Appendix 2.

2.4 Fire Protection System Test

Prior to siting, the halon and argon fire protection systems were deliberately discharged and the concentrations of fire suppressive gases monitored in the MPU-1 trailer for a period of approximately one hour (Appendix 8).

Halon R122 fire suppressant gas was discharged in the oil processing and control room areas and its concentration was monitored directly by a dedicated recording analyzer. This test was carried out by Levitt Safety Company representatives.

Argon gas was discharged in the sodium handling compartment at the rear of the trailer and its concentration was determined indirectly by monitoring the concentration of residual CO_2 in the compartment by an infrared absorption method. This test was carried out by Ontario Hydro personnel.

3.0 RESULTS

3.1 PCB Destruction Data

Representative PCB dechlorination test data obtained during the research tests are given in Table 1 and discussed below.

3.1.1 Service Quality Oil

Examples 1-5 of Table 1 show the results of sodium addition to service quality insulating oil contaminated with 120 mg/kg of Aroclor 1260 and 60 mg/kg of tri-and tetrachlorinated benzenes (T/TCB). PCB contamination was reduced to <2 mg/kg in as little as 15 minutes with a sodium/chlorine ratio as low as 13/1.

At an initial oil temperature of 115°C, the average reaction time for examples 2 to 5 single sodium addition tests was 22.5 minutes and the average sodium/chlorine ratio 13.5 to 1 for the successful dechlorination of 120 mg/kg PCB and 60 mg/kg T/TCB in service quality (sludge-free) insulating oil.

3.1.2 Scrap Quality Oil

Decontamination reaction results from 550 mg/kg[1] and 700 mg/kg PCB contaminated oil from TK-3, site L-21 and 7000 mg/kg PCB

[1] The 550 mg/Kg oil resulted from the addition of 700 mg/kg oil to a mixing vessel containing a heel of decontaminated oil.

TABLE 1

REACTION PARAMETERS AND RESULTS FOR MPU-1
PROCESSING OF PCB CONTAMINATED OIL

Test Number	PCB Content (mg/kg)		Reaction* Temperature (°C)	Reaction Time (Minutes)	Sodium/Chlorine Molar Ratio**	
	Initial	Final				
1	120	<2	115-120	45	21	***
2	120	<2	115-120	30	15	
3	120	<2	115-120	30	13	
4	120	<2	115-120	15	13	
5	120	<2	115-120	15	13	
6	550	<2	110-120	15	15	
7	700	<2	120-130	60	16	***
8	700	<2	110-120	60	14	***
9	700	<2	110-120	60	14	***
10	700	<2	110-120	35	14	
11	700	<2	110-120	35	12	
12	700	<2	110-120	30	12	
13	700	<2	110-120	30	11	
14	700	<2	110-120	120	8	***
15	700	5	120-130	120	7	***
16	700	15	120-130	60	6	***
17	7000	<2	110-135	60	2	***
18	7000	<2	110-135	45	2	

* Temperature range includes the temperature rise due to reaction.

** The sodium/chlorine mole ratio includes the chlorine from all sources (PCB and chlorinated benzenes). The chlorinated benzene content of the oil was approximately 50% of the PCB content in all cases.

*** Sodium added in stages for these tests.

contaminated oil from TK-1, site L-21 are tabulated for tests 6-16, and 17-18, in Table 1, respectively. All of the input oils from runs 6 to 18 inclusive were scrap quality and contained approximately 1 percent by weight of filterable solids.

Excluding tests for which sodium was added in stages, the average reaction time and sodium/chlorine mole ratio for 700 mg/kg oils were 32.5 minutes and 12/1, respectively (tests 10-13). Run 6 for the oil containing 550 mg/kg had a reaction time of 15 minutes with a slightly greater sodium/chlorine ratio of 15/1. For single sodium addition test 18, 7000 mg/kg contamination was removed using a much reduced mole ratio of 2/1 and a reaction period of 45 minutes.

The presence of 1 percent by weight sludge in the input oil did not have a major effect on reaction efficiency as the amount of sodium which reacted with the acidic sludge was hidden by the relatively large quantities of sodium used during the PCB dechlorination.

3.1.3 PCB Destruction Performance Summary

Linear regression fits of $\log_e$ (PCB Content) versus reaction time and $\log_e$ (sodium/chlorine molar ratio) versus PCB content are presented in Appendix 3 and an interpolation table based on the results is presented as Table 2. This table indicates what is expected of the MPU-1 in service.

TABLE 2

INTERPOLATION TABLE FOR MPU-1 PERFORMANCE AT 110°-120°C

Initial PCB Content (mg/kg)	Reaction Time For Destruction To <2 mg PCB/kg (minutes)	Sodium/Chlorine Molar Ratio*
50	16	14.1
100	20	13.9
120	21	13.8
200	24	13.5
300	26	13.1
400	28	12.8
500	29	12.4
700	31	11.7
1000	33	10.8
3000	39	6.2
5000	42	3.5
7000	44	2.0

* Assumes an additional T/TCB content of 50% of the measured PCB content.

3.1.4 Temperature Effects

A 120°C starting temperature was used in examples 7, 15 and 16 to determine if a higher average temperature could significantly reduce the time or sodium requirements for successful dechlorination. Comparing the parameters and results for tests 7 and 8, and tests 14 and 15, no obvious advantage is realized by increasing the initial batch temperature to 120°C. This result is at variance with laboratory findings /1/ which indicated an Arrhenius type increase in reaction rate with increasing temperature. However, the inconsistency was not considered worth pursuing during this research commissioning program as the 110°C operation temperature provided acceptable performance. In addition, lower operating temperatures result in savings in heat up time and energy costs, and provide an added margin of safety against thermal excursions exceeding the flash point (155°C) of the insulating oil.

3.1.5 Staged Sodium Addition

Early exploratory tests, in which sodium was added in several stages, are identified in Table 1 by the symbol: "***". The intervals between sodium additions were generally 30-120 minutes, depending upon the extent of data gathering required, but were occasionally 1-3 days due to weekend shutdowns or other stoppages. In Test 17, the first dechlorination run of 7000 mg/kg PCB input oil, the sodium was introduced at 10 minute intervals as a precaution against thermal runaway.

The step-wise addition of sodium had an adverse effect on reaction time (tests 1, 7, 8, 9 and perhaps 14 and 15) and sodium/chlorine molar ratio (tests 1 and 7), presumably because active sodium was a limiting reactant in the early addition steps. Single addition tests suffered from reactant loss only near the end of the reactions when PCB became the limiting reactant.

Examples 14-16 show that significant reductions in PCB content can be achieved for 700 mg/kg oil treated with sodium at sodium/chlorine ratios of 6-8, however, these reactions were relatively slow and erratic and are not considered representative of MPU-1 performance.

3.1.6 Reaction Rate Enhancement by Water Addition

It has long been recognized/2-4/ that free (nascent) hydrogen atoms are required in the oil to complete the PCB dechlorination reaction by substituting chlorine on the biphenyl structure. While some scrap oils may contain sources of free hydrogen, the present work indicates that reaction inhibition is possible in scrap oils containing high levels of PCB because available

hydrogen is quickly scavenged. Further, dry, low level contaminated oil of service quality can also lack free hydrogen if significant degradation of oil components to generate hydrogen has not occurred. Injection of hydrogen gas during the reaction is a possible method of combating inhibition but this would require changes to the MPU-1 system and necessitate stocking hydrogen gas bottles on board the MPU-1. A simpler, safer method is the addition of a small volume of water to the reaction mixture to generate hydrogen in-situ, which was done successfully on a regular basis during the test program.

The effect of various water contents on the reduction rate of PCB in oil is discussed in Appendix 4 and illustrated in Figures 5 to 10 of the Appendix.

Average water quantities required for successful reaction are presented in TABLE 3.

TABLE 3

AVERAGE WATER QUANTITIES REQUIRED FOR SUCCESSFUL REACTION MPU-1 TESTS*

Initial PCB Content (mg/kg)	Average Water Added (mg/kg)	Number of Tests In Average	Water As a Percent of Total Required to Neutralize All Excess Sodium**
120	175	5	22
550-700	950	9***	30
7000	1750	2	29

* From Appendix 4.
** Excluding Sodium required for PCB and T/TCB Reaction.
*** Tests 14 & 15 excluded from average - initial water content values not available.

3.2 Materials Analysis

On average, each 1500 L oil batch processed discharged the following, in addition to product oil:

(1) 25 L centrifuge residue
(2) 60 ml exhaust vent condensate
(3) 6 L degassifier condensate

(4) 25 kg spent Fuller's earth
(5) 2.27 m^3 filtered nitrogen

The degassifier condensate includes a large quantity of input oil carried over due to foaming, as described in section 3.2.3, and the Fuller's earth weight is an average of only those tests where the column was used.

3.2.1 Centrifuge Residue

A representative centrifuge residue sample obtained from the storage tank TK-10 was analysed as described in section 2.3.3 and the results are presented in Table 4.

TABLE 4

ASTM D-123-83 ANALYSIS OF
MPU-1 CENTRIFUGE RESIDUE (PCB CONTENT <2 mg/kg)

Component	Percent by Weight
Filterable Oil	49.8
Asphalt and Tarry Matter	0.1
Fatty Acid Sodium Soaps	1.3
Unsaponifiables and Oil Held in Residue	10.9
Fatty Acid Esters	0.8
Sodium Chloride	30.9
Sodium Hydroxide	5.4
Sodium Carbonate	0.8

As expected, the major constituent of the centrifuge residue was oil (60.7%) either trapped in the residue or as filterable oil ejected by the centrifuge during automatic bowl cleaning operations. Second in quantity were the inorganic sodium chloride, hydroxide and carbonate salts totaling 37.1%, and formed during reaction of sodium with PCB, water and trace air present in the original contaminated oil. The remainder of the residue consisted of sodium soaps formed chiefly by sodium reaction with oil oxidation products in the input oil plus a small amount of fatty acid esters.

3.2.1.1 - Water Insolubles. Of the components listed in Table 4, filterable oil, asphalt and tarry matter, unsaponifiables and oil held in residue, a total of 61% by weight, would not be expected to dissolve in water. In fact the actual percentage of water insolubles totalled approximately 84 percent, indicating

significant retention of water solubles in the oil, believed due to the action of fatty acid sodium soaps and other trace emulsifying agents.

3.2.1.2 - Toxicity of Residue and Residue Leachate. To determine if the centrifuge residue would be defined as "Severely Toxic" under proposed Ontario Regulation 309/5/, an analysis was carried out for dioxins (PCDD) and dibenzofurans (PCDF). The results, presented in Table 5, show that both PCDD and PCDF concentrations are less than the 1 mg/kg provisional limit set out in Regulation 309 and therefore the waste is not considered severely toxic.

TABLE 5

ANALYSIS OF CENTRIFUGE RESIDUE FOR SEVERELY TOXIC CONTAMINANTS AS DEFINED IN PROPOSED REGULATION 309

Contaminant	Concentration (mg/kg)
Polychlorinated Dibenzodioxins (PCDD)	<0.000 001 *
Polychlorinated Dibenzofurans (PCDF)	<0.000 001 *

* Not detected at a detection limit of 1 ng/kg.

A sample of the centrifuge residue was subjected to leaching as described in Appendix 6, and the oil and water phases analysed for trace contaminants to determine if the centrifuge residue would fall within the definition of "leachate sensitive, leachate toxic or Acute hazardous" under proposed regulation 309. The analytical data are presented in Tables 6 and 7 for oil and water phases respectively.

TABLE 6

ANALYSIS OF 26 g OIL LAYER OF CENTRIFUGE RESIDUE LEACHATE
(Initial Mixture: 50 g residue plus 800 ml water)

Contaminant	Concentration (mg/kg)
Polychlorinated Biphenyl (PCB)	<5 *
Biphenyl	18
Polyphenyl	<10 **
Chlorinated Benzenes (T/TCB)	<5 *
Benzene	<5 *
Cyclohexane	<5 *

* Not detected at a detection limit of 5 mg/kg.
** Not detected at a detection limit of 10 mg/kg.

TABLE 7

ANALYSIS OF 924 g WATER LAYER OF CENTRIFUGE RESIDUE LEACHATE
(Initial Mixture: 50 g residue plus 800 ml water)

Contaminant	Concentration (mg/kg)
Polychlorinated Biphenyl (PCB)	<0.0002 *
Chlorinated Benzenes (T/TCB)	<0.0009 **
Chlorophenol	<0.013
Phenol	<2

* Not detected at a detection limit of 0.2 µg/kg.
** Not detected at a detection limit of 0.9 µg/kg.

As PCB is not present in the water layer to a concentration higher than 10 times the 0.003 mg/kg provisional limit set out in Schedule 4 of reference 5, the centrifuge residue is not leachate sensitive or leachate toxic under the regulation.

The total quantity of possible Schedule 2B contaminants (T/TCB, benzene, cyclohexane, chlorophenol and phenol) of reference 5 is less than 105 mg/kg for the 26 g oil layer and less than 4 mg/kg for the 924 g water layer yielding a total mass of schedule 2B contaminants for the initial 50 g residue sample of less than:

$$(105 \times \frac{26}{1000} + 4 \times \frac{924}{1000})/50 = 0.1 \text{ mg/g}$$

Considering a maximum centrifuge residue generation rate of 22 kg per 1500 L batch, 12 batches/24 hour day, 31 days per month, the maximum emission of schedule 2B contaminants would be: <0.1 mg/g x 1000 g/kg x 22 kg x 12 x 31 = 0.82 kg per month. This total is less than the small quantity exemption of of 5 kg per month for schedule 2B material. Therefore the centrifuge residue is not a hazardous waste under proposed regulations.

3.2.1.3 - Corrosivity of Leachates. The initial pH of leachate water from the centrifuge residue was 12.7, a figure higher than the corrosive waste limit of 12.5 of Regulation 309. However, analysis of centrifuge residue samples from oils with initial PCB contents of 120 mg/kg, a range closer to what will be treated under field conditions than the average waste of the research tests, yielded an average pH of 12.4. The pH of centrifuge residues in field operation are expected to be close to the "corrosive" definition limit, however, if slightly in excess of 12.5 they could be adjusted to <12.5 by the addition of dilute hydrochloric (muriatic) acid. For example, a 17 L

addition of 1N HCℓ to a drum (205 L) of centrifuge residue with an initial pH of 12.7 would lower the pH to about 7.0, based on the volume of 1N acid required to neutralize the leachate sample water layer discussed above. If desired, dilute acetic acid could be substituted for the hydrochloric acid.

The centrifuge residue is therefore non-corrosive or can be made non-corrosive by the addition of dilute hydrochloric or acetic acid.

3.2.1.4 - Slump Test. A slump test to determine if centrifuge residue could be classed as a solid under Proposed Regulation 309 was not carried out as the material poured easily due to its large oil component and is a liquid. The centrifuge residue therefore falls under the definition of a Liquid Industrial Waste and should be classifiable from Table 1 of Reference 5, "MOE Waste Classes". The closest match appears to be MOE waste class 251, "Waste oils/sludges from petroleum refining and marketing". However, the inorganic portion, if separated, would fall under class 133, "Brines, chlor-alkali sludges and residues" due to its high salt content.

3.2.2 Mixer Condensate and Vent Gas

3.2.2.1 - Condensate Composition. During research testing nitrogen cover gas flowed from the mixers, through a condenser and carbon filter and then to the atmosphere. Approximately 60 ml of condensate per batch processed was collected and a pooled sample was analysed for trace contaminants. The analytic data are presented in Table 8.

TABLE 8

MPU-1 EXHAUST VENT CONDENSER CONDENSATE

Component	Total Collected (L)	Concentration
Water	1.10	95 percent by weight
Oil	0.06	5 percent by weight
PCB Content of Water Layer	-	<2 µg/kg
PCB Content of Oil Layer	-	<2 mg/kg
Chlorinated Benzene Content of Oil Layer	-	93 mg/kg

The PCB content of the condensate was lower than expected, based on pre-operational vapour pressure calculations which indicated that condensate PCB content could be as high as 25 percent of input oil PCB content, that is about 1230 mg/kg, on average. However, the vapour pressure calculations assumed all vapours condensed contained PCB in equilibrium with mixer tank oil at 120°C. In practice, the head space gas temperature where the gas exited via a 6.4 mm dia (0.25 inch) line was at most 60°C and dropped rapidly to about 25°C within a meter of the mixing vessel. Apparently the first 1 m section of piping acts as a crude condenser for hot vapours, which trickle back to the mixing tanks.

Because the condensate is virtually all water and because a small amount of water is required for reaction acceleration, it seems reasonable to use vent condensate, when available, as an additive to the mixer tank thus eliminating this material from consideration as a waste product.

3.2.2.2 - Vent Gas Analyses. Vent gas was sampled continuously during the reaction period of each test as this was the only time that exhaust gases were released from the mixers. Because the reaction period was short, 15 minutes to 1 hour, the gas concentration data obtained are approximately one-half hour averages and can therefore be compared with one-half hour limits set out in proposed regulations. The gas concentrations data obtained are presented in Table 9. Data for the column titled: "Quantity of PCB Destroyed while Sampler Operating" were calculated from the average PCB concentration and number of batches processed while gas sampling was taking place, as described in Appendix 7.

Regardless of the quantity of PCB destroyed during the sampling period, the vent gas from the process contained less than the proposed regulatory limit of 450 ng PCB/m^3 and less than the proposed limit on PCDD/PCDF emission given by the expression:

$$\frac{\text{PCDD}}{450\ \text{pg/m}^3} + \frac{\text{PCDF}}{450\text{x}50\ \text{pg/m}^3} = 1 \qquad [1]$$

The above are provisional Provincial one-half hour limits set out in proposed Ontario Regulation 293, plus amendments, (reference 6).

TABLE 9

VENT GAS ANALYSIS - MPU-1 OIL PROCESSING

Sample Number	PCB Destroyed While Sampler Operating		Gas Volume Sampled (L)	Vent Gas Contaminant Concentration (ng/m^3)				
	Mass (kg)	Average Concentration -PCB in Input Oil (mg/kg)		PCB	T/TCB	Chlorophenol	PCDF	PCDD
1	0.13	85	4250	<24[1]	<12[3]	<200	--	--
2	1.88	375	2320	<43[1]	<22[3]	<100	--	--
3	3.25	338	1580	152	76	<80	--	--
4	23.63	2100	1180	186	220	<50	--	--
5	26.13	1239	1870	--	--	--	<0.053[2]	<0.053[2]

[1] Not detected in sample at a detection limit of 0.1 µg.
[2] Not detected in sample at a detection limit of 0.1 ng.
[3] Not detected in sample at a detection limit of 0.05 µg.

The observed concentrations for T/TCB and chlorophenol emissions are less than the respective MOE guidelines of 100 $\mu g/m^3$ and 60 $\mu g/m^3$ for a one-half hour average.[2]

3.2.2.3 Carbon Filter Efficiency

The average nitrogen cover gas PCB concentrations upstream and downstream of the carbon filters located at the end of the exhaust gas train were 1080 ng/m^3 and 133 ng/m^3, respectively, when averaged on a per batch basis (Appendix 7) compared to an expected 1250 ng/m^3 and 0.5 ng/m^3 based on vapour pressure calculations and carbon absorption data. While the pre-filter PCB concentration was close to the expected value, the post filter value was higher than expected, with each of the two carbon filters causing a 1/2.8 reduction in PCB content rather than a 1/50 reduction. This is tentatively attributed to a more rapid than expected breakthrough of the filters, probably around the "2 kg PCB destroyed" point, at which time PCB was detected in the output stream. It is noted that after processing approximately 29 kg of PCB, the equivalent of 116 batches of 200 mg/kg oil, the PCB content of the exit gas at the point of emission was still significantly less than one-half of the point of impingement safety limit of 450 ng/m^3. It is therefore expected that the two carbon filters would require replacement on a 200 batch basis or every 50 operating days, assuming four 200 mg/kg batches per 8 hour day.

Analysis of the output gas stream for hydrogen and oxygen was performed during and after sodium and water injections and the data are presented in Table 10. Except for the exceptional case noted in the Table, the hydrogen content is less than the explosive limit of 4 percent by volume in air.

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[2] The guideline limits are for 1, 2, 4 trichlorobenzene and pentachlorophenol, respectively/7/.

TABLE 10

AVERAGE OUTPUT GAS ANALYSIS FOR
HYDROGEN AND OXYGEN - MPU-1 TESTS

Test Condition*	Hydrogen % By Volume	Oxygen % By Volume
Prior to Sodium Addition	Not detected	Not detected
After Sodium Addition	1	Not detected
After Sodium & Water Addition	2	Not detected
Exceptional Case: Water Added To React A Large Excess of Sodium - A Contingency Case (Approximately 2 Kg Sodium Plus 5 Kg Water)	24	Not detected

* Degassifier off

3.2.3 Degassifier Condensate and Vacuum Pump Seal Oil

3.2.3.1 - Degassifier Condensate. Condensates removed from input oil by the degassifier system during research tests were collected in TK-2 (see Figure 10 of Appendix 1 for equipment placement) and a pooled sample was analysed. The analytical data is presented in Table 11.

TABLE 11

MPU-1 DEGASSIFIER CONDENSATE ANALYSIS

Component	Total Collected (L)	Concentration
Water	4.1	5 wt %
Oil	102	95 wt %
PCB Content of Water Layer	-	1.4 µg/kg
PCB Content of Oil Layer	-	120 mg/kg
T/TCB Content of Water Layer	-	2.5 µg/kg
T/TCB Content of Oil Layer	-	33 mg/kg

The large oil quantity was primarily the result of unanticipated carryover of input oil foam from the degassifier in early tests due to defective foam controller operation in the degassifier. As detailed in Appendix 1 the automatic alarm system detected the abnormal condition, and foam levels were subsequently controlled manually. Because the carryover was input oil, it contained PCB.

The PCB content of the water layer is relatively low considering the PCB content of the oil layer and the water component could be released to sanitary sewers as the PCB content is less than the proposed limit of 3µg/kg /6/. Because of the unexpected oil foam carryover, it is not yet known if condensed water from future operation will be contaminated with PCB or oil. However, in a worst case, collected oil could be returned to the input oil tank and the water layer used for reaction acceleration by metered addition from additive tank TK-6.

3.2.3.2 - Seal Oil. Degassifier vapours from the degassifier condenser pass through a quantity of PCB free insulating oil (seal oil) prior to joining the output gas stream from the mixer tanks. Analysis of the seal oil for PCB at various times during the research tests (Table 12) indicates minimal transfer of PCB contamination from the input oil to the degassifier vacuum system.

TABLE 12

DEGASSIFIER VACUUM PUMP SEAL OIL
PCB CONTENT - MPU - 1

Sample Number	PCB Content (mg/kg)	Running Average PCB Content of Input Oil (mg/kg)	Cumulative PCB Destroyed (kg)
1	<2	0	0
2	5	375	4
3	22	1120	24

From Table 12 it appears that the PCB content of the seal oil keeps step, approximately, with the cumulative amount of PCB passed through the system and destroyed. At the rate of contamination experienced in the research tests, about 200 batches of 200 mg/kg PCB contaminated oil could be processed before the vacuum pump seal oil contamination would reach 50 mg/kg and become a PCB waste. In service, vacuum pump seal oil would be checked regularly for PCB and replaced with new insulating oil when the PCB content exceeded a pre-set limit, tentatively 25 mg/kg. The PCB contaminated seal oil would be added to the feedstock and dechlorinated.

3.2.4 Fuller's Earth

A leachate test of spent Fuller's earth was carried out following the procedure of Appendix 6 to determine the level of trace contaminants in this waste. The analytical results are given in Table 13.

TABLE 13

ANALYSIS OF WATER LAYER OF FULLER'S EARTH LEACHATE
(initial mixture: 50 g Fullers Earth plus 800 ml water)

Measurement	Concentration (mg/kg)
Polychlorinated Biphenyl (PCB)	<0.0002 *
Chlorinated Benzenes (T/TCB)	<0.0009 **
Alkalinity - As Sodium Hydroxide	90
pH	9.2 (pH Units)

* Not detected at a detection limit of 0.2 µg/kg.
** Not detected at a detection limit of 0.9 µg/kg.

As expected, the Fuller's earth leachate water does not contain significant quantities of PCB or T/TCB and the leachate is not classed as corrosive as the pH is less than the 12.5 limit of proposed regulation 309.

Oil removed from the Fuller's earth (approximately 35 percent by weight) was not analysed for toxic contaminants as this is the same oil which constitutes about 58 percent of centrifuge residue and is therefore assumed to contain contaminants in about the same quantities as given for the centrifuge residue in Table 5.

3.2.4.1 - Slump Test. A slump test was attempted on the Fuller's earth to determine if the material could be considered as a solid, however the material lacked the cohesiveness and plasticity required for the test to be applicable. Fuller's earth is considered a granular, solid waste and therefore not subject to the general registration requirements.

3.2.5 Output Oil

3.2.5.1 - Toxic Contaminants. In addition to the PCB analyses of Table 1, four pairs of oil samples were also analysed for T/TCB and chlorophenols. The data are presented in Table 14.

TABLE 14

TRACE CONTAMINANT ANALYSIS - MPU - 1 OUTPUT OIL

Sample Identifier	Contaminant Concentration (mg/kg)		
	PCB	T/TCB	CHLOROPHENOL
Initial Oil - Test 8	700	390	--
Final Oil - Test 8	<2	<2	<3
Initial Oil - Test 1	120	81	<5
Final Oil - Test 1	<2	<5	<5
Initial Oil - Test 18	7000	3010	260
Final Oil - Test 18	<2	<5	58
Initial Oil - Test 2	120	64	270
Final Oil - Test 2	<2	<5	104

Neither PCDD nor PCDF was detected in oil saturated (58 percent oil) centrifuge residue and therefore these materials cannot be

present in the output oil at greater than 1.7 times the detection limit for these substances, that is 1.7 x 1 ng/kg. This level is far lower than the proposed Ontario Regulation 309 limitation of 1 mg/kg for severely toxic contaminants.

The null result for PCDD/PCDF in the mixer cover gas prior to carbon filtering (the vapour component of which could contain up to 95 percent oil based on the condensate analysis of Table 8) supports the view that PCDD or PCDF are not present in the output oil in detectable quantities.

3.2.5.2 - Power Factor - Effects of Moisture. Typical oil quality data for MPU-1 treated oils are presented in Table 15, where it is noted that power factor is the most sensitive characteristic with respect to treatment. The other oil characteristics are little affected by the process.

In the early oil quality tests a coarse, relatively wet Fuller's earth was used. As noted by the increase in water content in going from the centrifuge ("Centrifuge Output" of Table 15) to the Fuller's Earth Column ("Coarse and Wet" FE tower output of Table 15) this material failed to dry the output oil. In addition the power factor was not reduced to an acceptable level. A change of material to a dry, fine grain (250 μm) Fuller's earth resulted in acceptable column performance as indicated by the "Fine and Dry" FE tower output column of Table 15.

The high power factor for oil from the centrifuge was unexpected based on earlier laboratory work/1/. However water addition was not a part of the previous studies and may have contributed to the retention of particulates in the oil and the presence of traces of water soluble compounds, as well as being a source of contamination itself.

The power factor of oil obtained from coarse and wet Fuller's earth was reduced to an acceptable level by either refiltering through dry Fuller's earth or blotter type filter paper, as shown in Table 16.

TABLE 15

OIL QUALITY TEST RESULTS - MPU-1 TREATED OIL

Test	New Oil Requirements (M-104M-79)	Input Oil	Centrifuge Output	Fuller's Earth Tower Output*	
				Coarse & Wet	Fine & Dry
Steam Emulsion Number (S)	Max 60	46	37	31	23
Water Content (mg/kg)	--	22	18	19	14
Power Factor @ 100°C (%)	Max 0.5	0.43	10.8	1.86	0.47
Dielectric Strength (kV)	Min 26	25	34	39	35
Neutralization Number (mg kOH/g)	Max 0.03	0.01	0.01	0.01	0.01
Interfacial Tension (mN/m)	Min 35	44.7	40.2	42.4	43.7
Relative Density @ 15°C	Max 0.906	0.862	0.862	0.862	0.862
ASTM Colour Value	Max 1	0.5	0.5	0.5	1.0-
Pour Point (°C)	Max -46	OK-@-46	OK-@-46	OK-@-46	OK-@-46
Viscosity @ 37.8°C (mm^2/S)	Max 10	8.5	8.4	8.6	8.5
Flash Point (°C)	Min 146	146	146	146	146
Fire Point (°C)	--	160	160	160	163
Oxidation Stability	Pass	Pass	Pass	Pass	Pass

* Fuller's Earth Used in Tests 15 and 16 was coarse (600 µm).
Fuller's Earth Used in subsequent tests was fine (250 µm).

TABLE 16

IMPROVEMENT OF SUBSTANDARD OIL

Sample	Power Factor at 100°C (%)		
	Untreated	Retreated with Dry Fuller's Earth	Filtered Through Blotter Type Filter Paper
1	1.86	0.06	-
2	1.86	-	0.22

To ensure that Fuller's earth for MPU-1 operations remains dry prior to use it should be acquired in polyethylene lined bags as the material is hygroscopic.

4.0 MPU-1 PERFORMANCE CHARACTERISTICS

4.1 Performance Summary

In Table 17 the present and future performance characteristics of the MPU-1 facility are compared to target values established in consultation with Transmission Stations personnel. The future performance characteristics refer to the MPU-1 following modification required to improve operating characteristics identified in Appendix 1. Except perhaps for centrifuge residue output, which is likely to be about 35 percent above the target, the MPU-1 should perform on target with respect to the process parameters of Table 17.

It should be noted that the "actual" processing capacity of Table 17 was the best performance obtained during the tests and could not be maintained due to the compounding of operating restrictions noted in Appendix 1. To achieve this rate, the MPU-1 was run in the manual mode.

4.2 Fire Protection Systems

Test results for the argon and halon system discharges are presented in Appendix 8. (Research Report C85-1-K describing the argon tests, and Levitt Safety Discharge Test Report 5662 describing the halon 1301 tests).

4.2.1 Argon System

Prior to discharge the sodium compartment contained only air (21% O_2, 78% N_2 and 1% Ar) and a measured CO_2 content of 460 µL/L. At approximately 7 minutes after initiation of argon discharge the CO_2 content fell to a minimum of 40 µL/L, and the residual air content at this point was (40/460) x 100, or 9% by volume. The argon content was therefore 100 minus 9, or 91% at the 7 minute mark. At the 15 minute mark the average CO_2 concentration was about 150 µL, indicating an argon concentration of 67%.

In summary, the argon system achieves the target argon concentration of >90% within 7 minutes of discharge but falls steadily after that point. While this is acceptable from the point of view of extinquishing a sodium fire, the data indicate that a third argon cylinder discharged at about the 10 minute point would be required to maintain the argon concentration at a 90% level for 15-20 minutes. Consultation with fire protection personnel is required to determine if a third cylinder is necessary.

4.2.2 - Halon 1301 System

The average halon gas concentration in the oil processing compartment peaked at about 9% by volume, that is 2% higher than the 7% target value, in approximately 2 minutes. The concentration at head level (2 m) and chest level (1.4 m) decreased to 1% and 5%, respectively, in 15 minutes while the floor level (0.3 m) concentration remained at approximately 9%.

The main leakage areas for halon were lower vents which were subsequently modified with quillotine-type, positive vent closures to significantly reduce the halon loss rate.

5.0 CONCLUSION

1. Provided that modifications suggested in Appendix 1 are addressed, the MPU-1 facility will meet the design target values of Table 17, with the possible exception of centrifuge residue quantity.

TABLE 17

PRESENT AND EXPECTED FUTURE PERFORMANCE CHARACTERISTICS OF MPU-1

PARAMETER	Target[1]	Actual	Future
Processing capacity (batches/8h day)	4	3	4
Batch Size (L)	1200 - 1500	1250	1500
Degassified oil water content (ppm)	<50-100	100	100
Initial Oil temp (deg C)	120 - 140	110 - 115	110 - 115
Reaction time (min)	15 - 60	15 - 45	15 - 45
Sodium/Chlorine ratio[2]	5/1 - 15/11	2/1 - 14/1	2/1 - 14/1
Max. PCB input oil concn. (ppm)	7000	7000	7000
Max PCB output oil concn. (ppm)	<2	<2	<2
Output oil quality	Meets OH spec M-104M	Meets OH spec M-104M	Meets OH spec M-104M
Exhaust gas emissions[3] ($ng\ PCB/m^3$)	1-100	186 max	100 max
N_2 gas usage (cyl/week)	2	2	2
Centrifuge residue output -- service quality oil (L/4800L)	30 - 45	45 - 80	60
Centrifuge residue output -- Scrap quality oil (L/4800L)	60 - 120	120 - 160	120
Fuller's Earth consumption (% by wt)	0.2 - 0.5	1.5 max	0.5
Gas chromatograph[4] analysis time (min)	10 - 30	15 - 30	30

[1] D. Bray, "MPU-1 Commissioning at Kipling Site - Performance Targets", Minutes of Meeting December 6, 1984, Location A403, Research Div. File No. 837.341

[2] Depends upon input PCB concentration and impurities in oil.

[3] Depends upon carbon filter pack replacement schedule.

[4] Includes sample preparation time.

6.0 RECOMMENDATIONS

1. Filtering the output oil through a 0.5 μm - 1.0 μm mesh, portable oil filter is recommended to guard against the carryover of Fuller's earth fines or other fine solids into the output oil tank. Minimal carryover is expected, but it could have an adverse effect on power factor and dielectric strength if it is not removed. The filter could be attached between the MPU-1 output oil connection and oil transfer hose.

2. Thorough retesting of the MPU-1, following modification to address the concerns identified in Appendix 1, is recommended.

3. Degassification of the output oil prior to use in transformers is recommended as the water content of the output oil may be above acceptable levels.

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APPENDIX 1

OIL PROCESSING DETAILS

The Mobile Processing Unit (MPU-1) is designed as a transportable system consisting of two process vessels, oil reconditioning equipment, chemical reagent (sodium) injection system, laboratory and necessary controls mounted in a 13.7 m (45 ft) closed trailer. Equipment placement is shown schematically in Figure 2.

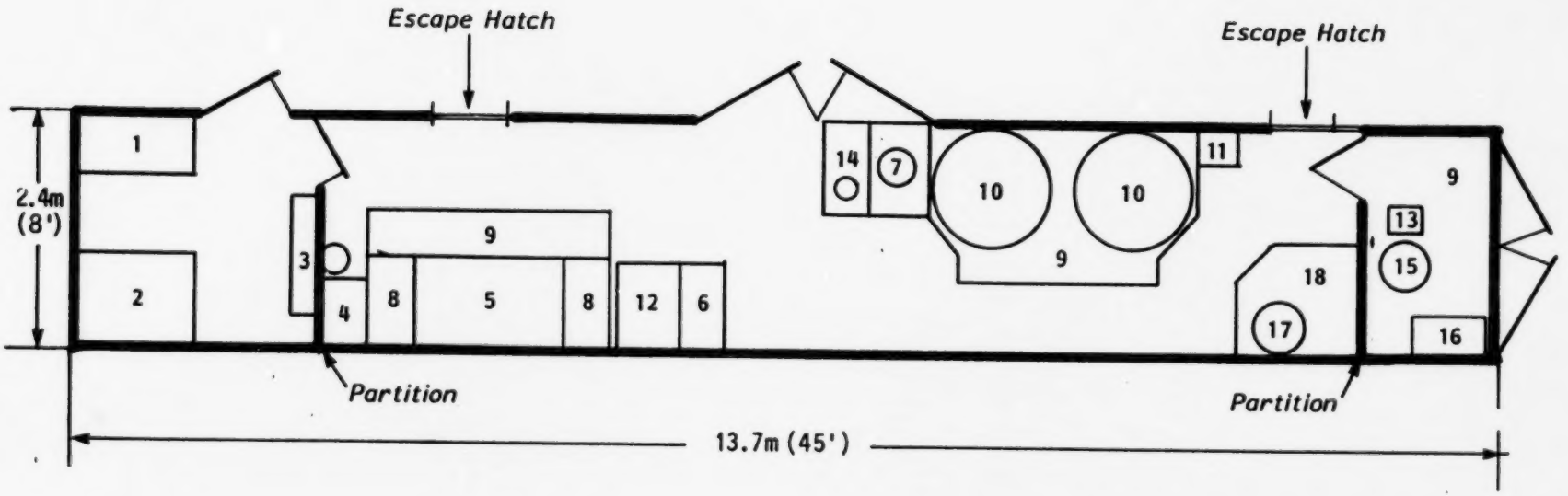
Oil treatment is a batch process and follows the process flow depicted in Figure 3. Contaminated oil is fed to the process unit by a feed pump, A, which transfers the oil to a heater, B. The heater raises the oil temperature to about 80°C so that subsequent treatment in degassifier, C, will efficiently remove suspended water and some dissolved water from the oil.

From the degassifier the oil flows through heat exchanger, D, and heater, E, which heat the oil to a required process temperature of approximately 110°C. The heat exchanger, D, transfers heat from hot, decontaminated, output oil to cooler, PCB contaminated, input oil. The heated input oil then flows to one of two mixing tanks to await decontamination. Two mixing tanks are used so that oil input and output processes may be carried out at the same time. This allows heat recapture at the heat exchanger and also the use of lower capacity equipment than would be required in a comparable one tank design.

In the decontamination step a small amount of molten, metallic sodium dispersed in oil is injected from a reagent preparation system, I, into the mixer, where it is agitated with the oil for approximately 15 minutes. At the end of the mixing period the PCB content of the oil is typically less than 2 mg/kg and the oil can be pumped from the processing trailer to a storage tank. As the oil passes from the trailer it is centrifuged and filtered to remove insoluble oil residues and improve oil quality.

The remainder of this appendix discusses the operation of various MPU-1 subsystems and observations made during the research tests. On the basis of the research experience equipment modifications are being carried out by the manufacturer to address all the identified items of concern.

The relative placement of equipment referred to in the following is shown schematically in Figure 4.



(A) Control Area

1 *Lab Bench*
2 *Electrical Service*
3 *Controls/Alarms*
4 *Fire Protection System*
9 *Spill Trays*
(The trailer floor is also a 13.7 x 2.4m x 0.3m spill tray)

(B) Oil Input/Output

5 *Degassifier*
6 *Heat Exchanger*
7 *Clay Treatment Unit*
8 *Oil Heaters*
17 *Centrifuge*

(C) Treatment Section

10 *Mixing Tanks*
11 *Additive Tanks*
12 *Vapour Condenser*
14 *Nitrogen Supply*
18 *Waste Storage Tank*

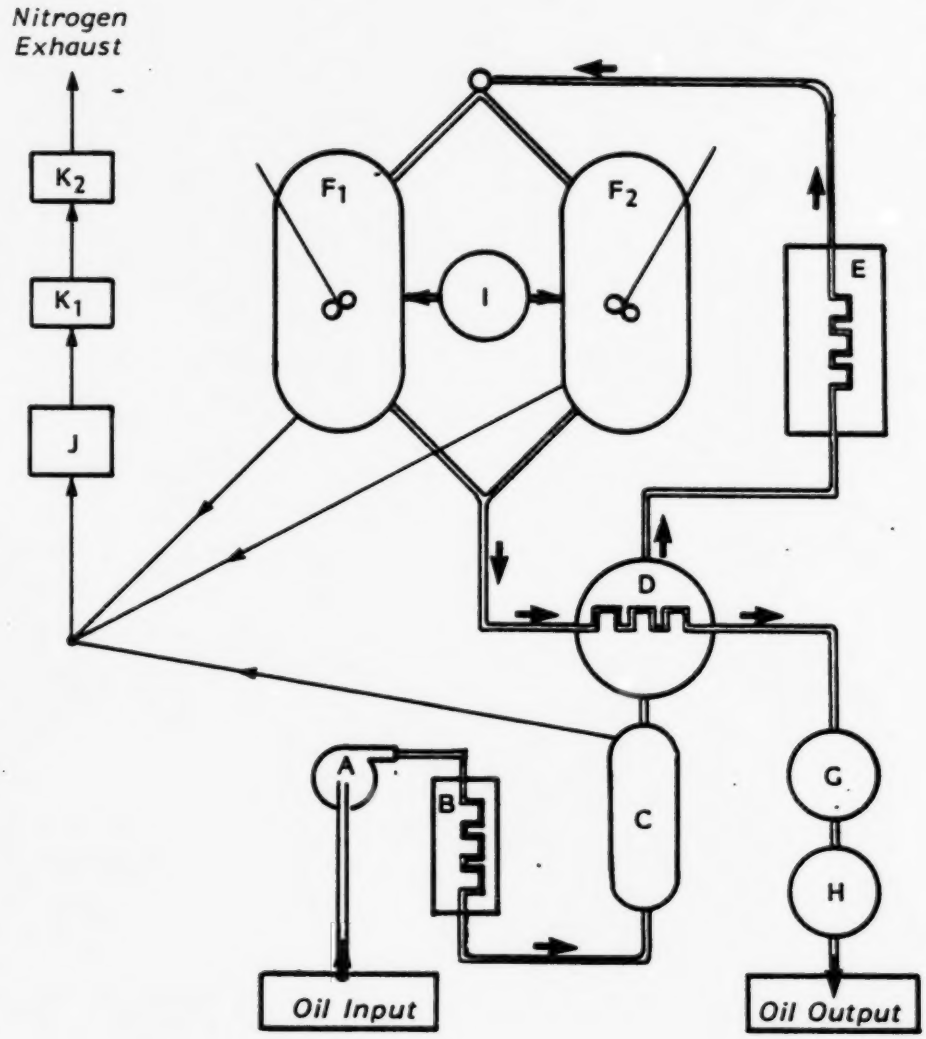
(D) Sodium Injection

13 *Dispersion Mill*
15 *Sodium Reservoir*
16 *Sodium Storage Cabinet*

FIGURE 2

EQUIPMENT PLACEMENT - MOBILE PROCESSING UNIT (MPU-1)

85-355
170130 RD



A	*Oil Feed Pump*
B, E	*Oil Heaters*
C	*Degassifier*
D	*Heat Exchanger*
F_1, F_2	*Mixing Tanks*
G	*Centrifuge*
H	*Fuller's Earth Filter*
I	*Sodium Injection System*
J	*Gas Chiller*
K_1, K_2	*Carbon Filters*

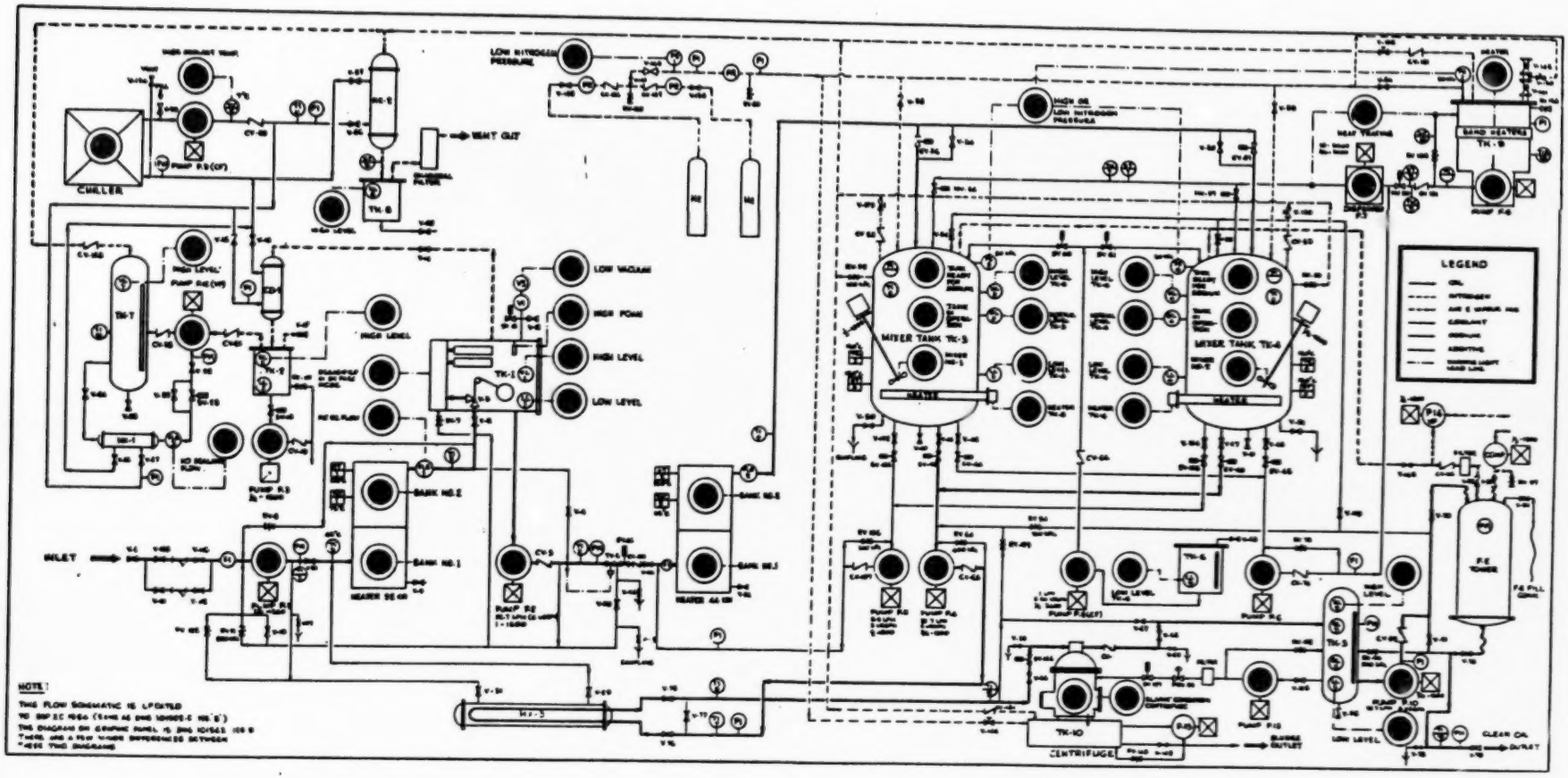
FIGURE 3

PROCESS FLOW DIAGRAM -
MOBILE PROCESSING UNIT (MPU-1)

FIGURE 4

MPU-1 FLOW SCHEMATIC AND COMPONENT

REFERENCE



A1.1 Degassifier System

The degassifier system consists of an input pump (P1), vacuum degassifier, bypass loop and various switching valves. Input oil is pumped through a primary oil heater and heated to approximately 80°C, so that subsequent degassification will efficiently remove trace water from the oil. To improve overall system efficiency, the oil can be circulated through an oil to oil heat exchanger/economizer (HX3) before passing through the primary heater. The heat exchanger transfers heat from hot decontaminated output oil to cooler PCB contaminated input oil. Any trace water vapour removed by this system is condensed in a chilled heat exchanger (CD-1) and collected in a closed tank.

During the research tests the following were noted:

(1) An operating temperature of 85°C was required to aid the overall rate of heating of the oil. A higher temperature was not possible due to possible degradation of the fibrous filter elements.

(2) At a setting of 85°C, 1500 L of input oil at 0-20°C required 1 h 22 minutes to pass through the degassifier and fill the mixer, with or without heat exchanger operation.

(3) Severe foaming was encountered with the majority of oil from TK-1 or TK-3, L-21 site and required that the operating pressure be held at 16 kPa, on average instead of at the best system pressure obtained: 6 kPa.

(4) Oil foaming was not suppressed by the automatic foam controller, resulting in the occasional carryover of PCB contaminated oil to condensate tank TK-2. However, the high level alarm on the condensate tank alerted the operator as required and carryover to the vacuum pump seal oil tank was prevented. Repair of the foam controller is required.

A1.2 Oil Heater and Mixers

After degassification, the oil is circulated through a secondary heater to bring it to operating temperature range (110 - 120°C), and then to one of the two mixer tanks.

An essential feature of all electric oil heaters installed in the MPU-1 is that the elements are not in direct contact with the oil, but are separated from it by the vessel or pipe wall.

The primary function of each of the two mixer tanks is to blend heated oil (110°C - 120°C) and sodium dispersion under an oxygen-free atmosphere. The tanks are thermally insulated, closed and each equipped with a low speed, off-center agitator impeller, heater and dry nitrogen gas blanket supply and exhaust systems, complete with vapour condensers and carbon filters. Each tank has a 1500 L (330 gal) process capacity and is equipped with a shut-off valve and tank drain and sampling valve at the lowest point from where oil is discharged.

During the research tests the following were noted:

(1) With the heat exchanger in use the input oil required 15-30 minutes to achieve 110°C -115°C; without the heat exchanger the time required was approximately 60-90 minutes. Hot, decontaminated oil was usually left in one of the mixers overnight to permit use of the heat exchanger for the first batch the following day.

(2) The mixing tank temperature rose to a maximum of 135-140°C when oil containing 7000 mg/kg PCB was processed. As this temperature is within 28°C (50°F) of the oil flashpoint (155°C) the MPU-1 would require MCCR[3] registration if oils containing 7000 or more mg PCB/kg are to be processed on a production basis in compliance with Ontario Regulation 84. Alternatively, the sodium addition rate can be reduced to reduce reaction temperature.

(3) Foaming sufficient to momentarily trigger the high level switch was observed when 7000 mg/kg oil was treated with sodium. This indicates formation of copious hydrogen gas, as noted in section 3.2.3.

(4) Mixer motors regularly shut off for brief periods for no apparent reason. The electrical disturbance this created caused the sodium injection timer and the reaction timer to reset. Both mixer motor operation and timer shielding require improvement.

(5) Input oil sludges from scrap quality oil, and reaction solids such as sodium chloride, accumulated in the mixer tanks and solenoid valves, probably because a 350 L heel of oil remained in the tanks after each batch and retained solids. A secondary effect of solinoid valve blockage was the overheating of oil in the main process heaters and consequent production of carbonized material which also

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3 Ministry of Consumer and Corporate Relations.

accumulated in the mixer tanks. Manual operation of the output pump to eliminate the heel was used after the accumulation problem was noticed.

(6) The sodium dispersion pickup loop requires 30-60 minutes of circulation to achieve an operating temperature of 100°C once the mixing tank is at 110°C due to an extremely low flow rate through relatively massive piping. Extra heating is required for the piping as sodium injection must be delayed until all systems are up to the required 100°C temperature.

A1.3 Centrifuge

The process output oil pump (P4), the centrifuge and either mixer tank can be connected by setting the appropriate valves to complete a reaction product removal loop. Solids removal is accomplished by the centrifuge with the solids-free oil passing either on to the clay filter or back to the same mixer tank for future processing, if necessary. If the oil is sent back to the mixer tank, it enters through a distribution header at the tank top.

The centrifuge is capable of continuously discharging solids without operator intervention. The output solids, which are flushed out by small quantities of decontaminated oil from service tank TK5, are contained in a holding tank TK10, and held for a later discharge to collection/storage drums. The nitrogen gas blanket and condensing system is connected to the holding tank for vapour control.

During the research tests the following were noted:

(1) At a centrifuge feed throttle setting of 0.6 the centrifuge output rate was slightly faster than the input rate of P-10, the output pump downstream of the centrifuge. The throttle setting was adjusted to 0.4 to compensate, and this supported an output flow rate of approximately 1000 L/h.

(2) If manual centrifuge shutoff valves V-66 and V-67 were not closed after the output system stopped, oil from TK-5 leaked back to the centrifuge until a low level in TK-5 triggered an alarm.

(3) Liquid discharge at the centrifuge frame drain occurred when automatic de-sludging took place, resulting in an oil layer on top of the centrifuge residue storage tank TK-10.

A drain line was installed to connect the frame drain to a 4 L reservoir as a temporary measure. A permanent line to TK-10 is required.

(4) Occasionally solids fouled the centrifuge feed throttle valve and restricted flow. Fully opening, then resetting the valve was necessary to dislodge the material.

A1.4 Fuller's Earth Clay Treatment Column

Clay treatment is effected by an in-line, column type filtration system. A bypass loop is provided so that oil not suitable for reclamation could avoid clay treatment. Special controls allow saturated Fuller's Earth clay to be ejected to a collecting drum placed outside the trailer.

The following were noted during the research tests:

(1) The column evacuating pump (P-14) was usually choked with oil prior to use because the flexible hose connecting the pump to the tower filled with oil when the tower was used. A valve at the hose connection point on the column is required.

(2) The air compressor on the column can be used to evacuate the tower and also the output hose.

(3) Initial flushing of the Fuller's earth with oil dislodges fine clay particles which contaminate the output oil. A 0.5 -1.0 µm portable filter unit might be used on the MPU-1 oil output line to trap such particles.

A1.5 Vapour Control System

Nitrogen cover gas is used to blanket the mixer tanks and a positive pressure of approximately 60 kPa (9 psig) is maintained at all times during operation.

Any gas overpressure in the mixer tanks is vented through a chilled, vapour condenser and two carbon filters in series to ensure that no PCB or oil vapour escapes from the trailer.

Seal oil for the degassifier vacuum system is not exposed to the atmosphere, therefore, any PCB removed from the oil during degassification will be held captive in the pump oil. The oil is monitored for PCB content and if it is contaminated with PCB, it can be replaced and used as feed material to the process.

The following were noted during the research tests:

(1) The nitrogen pressure controls are located in the sodium processing area, making access to them difficult.

(2) Nitrogen flow was not required during all processing stages, only during the reaction period.

(3) Because of foaming problems with the input oil, the degassifier pressure was kept relatively high by continuously bleeding air into the degassifier and, hence, into the vapour control system. This had the effect of increasing the flow of gas from the exhaust vent and changing the gas composition from nitrogen to a mixture of nitrogen and air when the degassifier was operating.

A1.6 Sodium System

The sodium dispersion injection system consists of a molten-sodium storage reservoir (TK9), transfer pumps (P5), two in-line dispersion mills (high shear mixers) (P7) and sodium dispersion transfer lines. The sodium dispersion in dry insulating oil is accomplished by the metered addition of molten sodium and hot oil to the mills for high shear agitation. The oil is supplied by a pump (P6), which cycles the hot oil to and from the mixer tanks.

Injection of sodium is controlled by a timer and a series of electrical interlocks which prevent system activation unless:

(1) all equipment and products are at operating temperatures;
(2) the nitrogen gas blanket is present and at correct pressure;
(3) mixer valving is appropriately set; and
(4) the required oil pumps and dispersion mills are operating.

The following were noted during the research tests:

(1) Heat traced lines containing sodium had to be heated to 120-130°C to assure flow. As sodium melts at 98°C, this indicates that areas of sodium piping were not being adequately heated by the heat tracing.

(2) Failure of the injection system due to sodium freezeout at valve MV-100 was common and traced to inadequate thermal insulation in the valve area. MV-100 presents a large area for heat loss and is situated in a wind tunnel formed by the dispersion mill cooling fans.

(3) A serious blockage of P-5, the submerged sodium pump, occurred and necessitated removal of the pump. Pump packing which had seized with the pump shaft was removed and replaced with a bushing. In addition, the pump head was drilled out to accommodate 1.27 cm (1/2") diameter tubing to replace the original 0.635 cm (1/4") tubing which tended to become blocked by sodium oxides.

(4) No more than 3 sodium bricks could be loaded at one time as the first one or two bricks blocked the tank area immediately under the sodium introduction port. Sodium addition was therefore halted until the sodium blockage melted. A design modification is required to prevent sodium pile-up at the introduction point.

(5) The sodium dispersion was relatively uniform but the majority of particles were larger than expected with diameters in the 15-25μm range, compared to the dispersion mill suppliers estimate of 5-10μm. Multiple passes through the mills are required to achieve smaller particle size and can be accomplished with minor piping changes.

A1.7 Controls

The operators may operate each step of the process independently or allow all functions to be controlled automatically. Manual operation can be selected for non-standard processing where certain steps might be omitted or prolonged, eg. degassifier or Fuller's earth bypassing, start-up and shutdown sequences.

Automatic operation is available for repetitive processing of normal oil stock, however, even in the automatic mode, a manual permissive start signal is required to initiate oil output from the mixer tank.

The only significant control system malfunction observed was the frequent resetting of the sodium injection and reaction timers. These electronic timers were susceptible to electromagnetic interference caused by breaker trips. Better shielding is required.

A1.8 On Board PCB Analysis

An AID Model 511 portable gas chromatograph with an electron capture system was used to analyse oil samples for PCB. It was observed that, with practice, sample preparation and analysis could be completed in 30-60 minutes depending upon the type of PCB present in the oil and its concentration.

The gas chromatograph, analytical procedure and results are discussed in detail in Appendix 3.

APPENDIX 2

MATERIALS COLLECTION AND ANALYSIS DETAILS

A2.3.1 Gases

Sipin SP-1 air samplers were set up to sample the nitrogen cover gas exhaust stream at points upstream and downstream of the final charcoal filter unit (see Figures 2 and 4 for equipment location). The samplers pulled gas through 0.8 cm dia. x 6 cm long tubes packed with florosil, or toluene-prewashed Amberlite[4] XAD-2 resin, at a rate of about 600 mL/min during plant operation. The florosil tubes were changed at approximately 100 h intervals and spent tubes were analysed for PCB, TCB and chlorophenols. The Amberlite tubes remained in place throughout the research tests and then were analysed for PCDD and PCDF.

An additional air sampler, equipped with a florosil tube, was set up to sample the ambient breathing environment in the vicinity of the main oil heater/mixer tank access area, and was analysed for PCB after 300 h of operation.

A2.3.2 Process Oils

Mixer tank samples for PCB or water content determination were taken from valve V-50, if TK-3 was operating, or V-51, if TK-4 was operating. The sample line was flushed with approximately 1 L of oil from the selected mixer tank prior to taking 1 to 3 30 mL oil samples.

Samples for PCB analysis were filtered immediately through a 15 cm dia, Whatman #1, filter paper and analysed as described in Appendix 5. Duplicate samples were sometimes mixed with 30 mL of distilled water and stored for later confirming analysis. One to four litre input and output oil samples for water content, oil quality tests and archive purposes were taken at valves V-115 and V-117, and V-73, respectively.

Valve locations are shown on Figure 4.

A2.3.3 Centrifuge Residue

Centrifuge residues were collected in 205L capacity, open head drums and 1 to 4 L samples were taken for archive purposes and detailed analysis.

---

4 Amberlite was used for long term sampling, as recommended by Ministry of the Environment personnel, as its performance is not significantly affected by accumulated moisture.

As the major components of the centrifuge residue closely resemble those in a crude soap thickened petroleum grease, that is, neutralized organic acids, saturated petroleum oils, alkali and inorganics; the residue was analysed using methods based on the American Society for Testing Materials (ASTM) Standard D-128-83, "Analysis of Lubricating Grease". This analysis provided gross composition to 0.1 percent by weight in terms of fatty acids, petroleum oil, polymeric material, asphalt and tarry matter, and inorganic residues.

Components obtained from D-128-83 were also analysed for biphenyl, polyphenyl, chlorine, sodium, trace metals, PCDD and PCDF.

A leachate test based on Ontario Regulation 309 (Appendix 1 of Reference 5), "Leachate Extraction Procedure" was carried out as detailed in Appendix 6. The leachate was analysed for PCB's and alkalinity.

A2.3.4 Condensates

Condensates collected from degassifier and oil processing systems were drained from TK-2 and TK-8, respectively, and stored in 4 L sample bottles or open head drums. The oil layers of the condensates were analysed for PCB and TCB while the water layers were analysed for PCB, TCB and chlorophenol.

A2.3.5 Fuller's Earth

A leachate test similar to that of section 2.3.3 was carried out on spent Fuller's earth collected in open head drums during research tests. Alkalinity and PCB content of the leachate were determined.

APPENDIX 3

PCB DESTRUCTION DATA PROCESSING

The average data for each of the three PCB concentration ranges of interest at 110-120°C are summarized in Table 18.

TABLE 18

AVERAGE MPU-1 REACTION RESULTS AT 110-120°C FOR SINGLE STAGE ADDITION PROCESSING OF PCB CONTAMINATED OIL

Initial PCB Content (mg/kg)	Reaction Time (minutes)	Sodium/Chlorine Molar Ratio*	Final PCB Content (mg/kg)
120	22.5	13.5	<2
700	32.5	12.0	<2
7000	45	2.0	<2

* The sodium/chlorine mole ratio includes chlorine from all sources: PCB + T/TCB.

Using the data of Table 18 the following least-squares regression lines were obtained:

$$\log_e(PCB) = 0.18086t + 0.702020 \quad [1]$$

and

$$\log_e(R) = -2.8038 \times 10^{-4}\ PCB + 2.65777 \quad [2]$$

where "PCB" is the concentration of PCB in mg/kg, t is reaction time in minutes and R is the sodium/chlorine molar ratio. The correlation coefficients for [1] and [2] were both 1.000.

Predicted T and R data from given PCB data are presented in Table 19. Equations [1] and [2] were used to produce the interpolation Table 2 of text.

TABLE 19

PREDICTED REACTION TIME AND MOLE RATIO DATA

Initial PCB Content (mg/kg)	Reaction Time (min)		Sodium/Chlorine Molar Ratio	
	Predicted	Actual	Predicted	Actual
120	21	22.5	13.8	13.5
700	31	32.5	11.7	12.0
7000	44	45	2.0	2.0

APPENDIX 4

EFFECT OF WATER ON PCB DESTRUCTION RATE

The effect of water content on the reduction rate of PCB in 6 representative oil batches (Table 20) are illustrated in Figures 5 to 10. Figures 5 and 6 show the reduction of PCB content with time in tests 2 and 3, in which very dry, (<10 mg/kg water) service quality insulating oil was decontaminated. As expected, in both cases water addition overcame an initial period of inhibition.

Figure 7 shows the progress of PCB reduction in test 5, a test using oil similar to that of tests 2 and 3, above, but containing 100 mg/kg water. No inhibition was noted in this oil and no addition of water was required during the dechlorination. Reaction inhibition in scrap quality oil is exhibited in Figures 8-10 where again water addition resulted in rapid drops in PCB contents in tests 15, 17 and 18.

TABLE 20

WATER ADDITION TO OIL IN MPU-1 DECHLORINATION TESTS

Test Number*	PCB Content (mg/kg)		Reaction Time (minutes)	Initial Water Content (mg/kg)	Added Water** (mg/kg)
	Initial	Final			
2	120	<2	30	<10	180
3	120	<2	30	<10	270
5	120	<2	15	120	none
15	700	5	120	120	480
17	7000	<2	60	140	1600
18	7000	<2	45	140	1600

* Correspond to Test Numbers in Table 1 in the body of the report.

** Water addition points are plotted on PCB content versus Time curves in Figures 5 to 10.

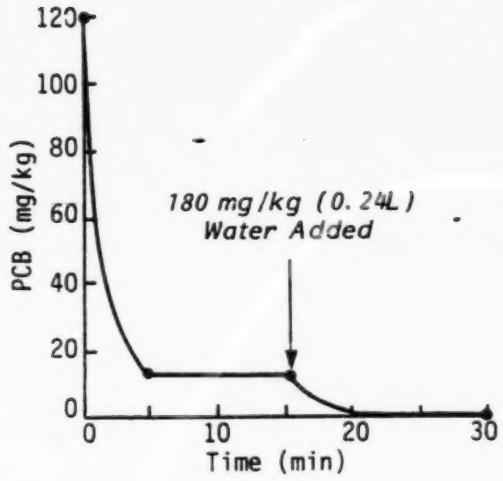

FIGURE 5
PCB CONTENT VERSUS TIME
TEST 2
Initial Water Content <10 mg/kg

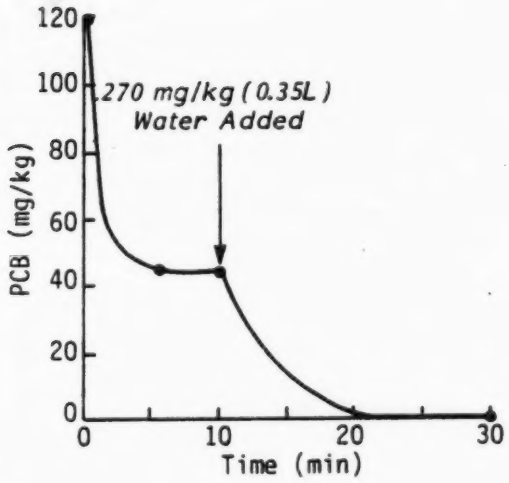

FIGURE 6
PCB CONTENT VERSUS TIME
TEST 3
Initial Water Content <10 mg/kg

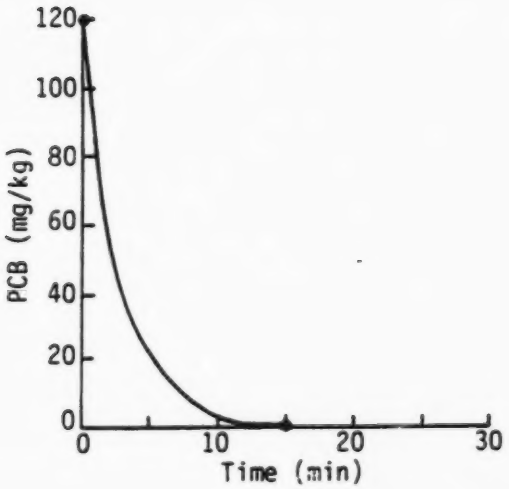

FIGURE 7
PCB CONTENT VERSUS TIME
TEST 5
Initial Water Content 120 mg/kg

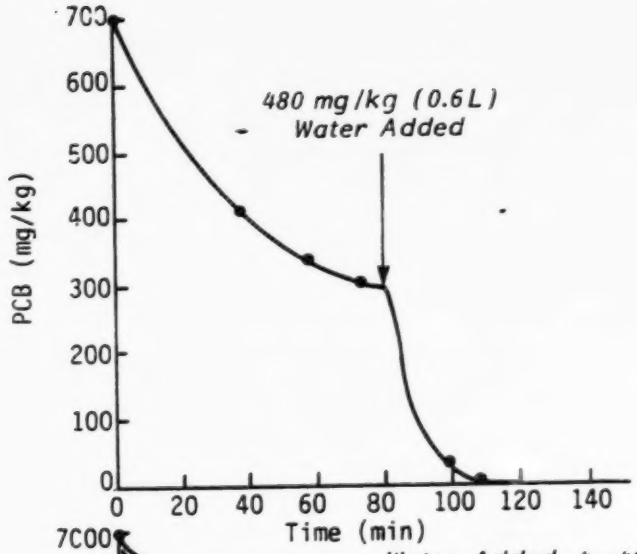

FIGURE 8

PCB CONTENT VERSUS TIME
TEST 15
Initial Water Content 120 mg/kg

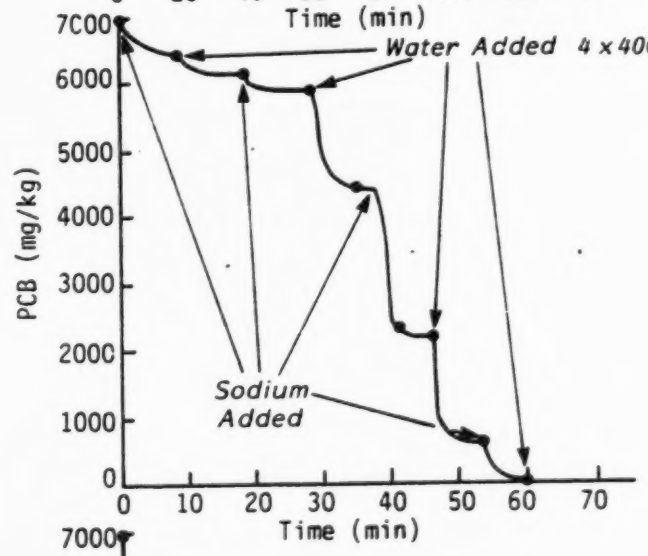

FIGURE 9

PCB CONTENT VERSUS TIME
TEST 17
Initial Water Content 140 mg/kg

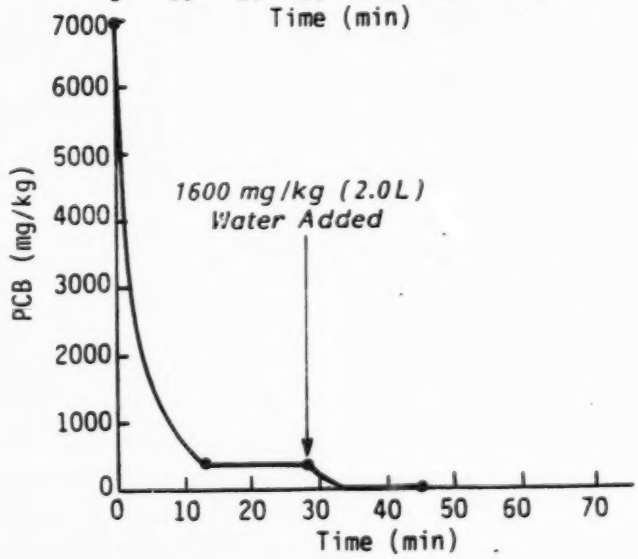

FIGURE 10

PCB CONTENT VERSUS TIME
TEST 18
Initial Water Content 140 mg/kg

The average water quantities required for successful reaction are presented in TABLE 21*.

TABLE 21*

AVERAGE WATER QUANTITIES REQUIRED FOR SUCCESSFUL REACTION-MPU-1 TESTS

Initial PCB Content (mg/kg)	Average Water Added - To 95% Confidence (mg/kg)	Number of Tests In Average	Total Water As a Percent Of Total Required to Neutralize All Excess Sodium**
120	175	5	22
550-700	950	9***	30
7000	1750	2	29

* Same as Table 3.
** Excluding Sodium required for PCB and T/TCB Reaction.
*** Tests 14 & 15 excluded from average - initial water content values not available.

For the MPU-1 mixer tanks, a water content of 800 mg/kg is equivalent to a 1 L water addition when a tank contains 1500 L of oil. Therefore dividing the water content figures of Table 21 by 800 yields the water additions required in litres for reaction acceleration, namely: 0.22 L, 1.19 L and 2.19 L, for concentrations of 120 mg/kg, 550-700 mg/kg and 7000 mg/kg, respectively.

As a rule of thumb for field operation the required water can be calculated as 0.18 L water/100 mg/kg PCB, up to 1200 mg/kg PCB, and 2.2 L water for 1200 mg/kg PCB or higher concentrations.

Successful reaction acceleration was achieved by adding water directly to hot oil/sodium mixtures and also by adding sodium to hot oil/water mixtures. Water injection to hot mixtures (>100°C) did not cause a significant pressure rise, 3 kPa being typical; or a detectable release of steam to the exit gas condenser. However, addition of water to oil prior to heating and sodium treatment avoided potential problems of concentrated sodium dispersion/water contact, as the added water was in a dissolved state prior to sodium introduction.

APPENDIX 5

PCB ANALYSIS DETAILS

A5.1 Sample Preparation

Sample preparation was as follows for samples collected after sodium reaction:

(1) Two new, 15 mm dia x 45 mm screw cap vials were placed in a wooden vial holder and to each was added 2000 µl of chromatographic grade iso-octane by means of a 1000 µL stroke volume Eppendorf pipette with disposable tip.

(2) A 200 µL aliquot of filtered[5] sample was added to vial #1 by means of a 200 µL stroke volume Eppendorf pipette with disposable tip and the vial capped with a foil-lined cap and agitated for approximately 30 s.

(3) A 200 µL aliquot of vial #1 contents was transferred to vial #2 using the 200 µL pipette and a new disposable tip. The vial was capped and agitated as in (2) above.

(4) A 1-10 µL sample of vial #2 contents was drawn up in a Hamilton #801, 10 µL syringe and injected into the onboard gas chromatograph.

(5) PCB quantification was usually based on the electron capture detector response for the eight most distinct peaks of Aroclor 1260. These peaks are shown on Figure 11.

For samples collected prior to sodium reaction the above method applied only if the PCB content was known to be less than about 200 mg/kg. For higher PCB content samples 200 µL of Voltesso 35 insulating oil was added to vial #2, the contents shaken, and a 200 µL aliquot of the mixture transferred to a new vial (vial #3) containing 2000 µL of iso-octane. Vial #3 was capped and agitated as in (2) above and injected as in (4) above.

A5.2 On-Board Gas Chromatograph

The Analytical System chosen for the analysis of PCB's in transformer fluid was the AID Model 511 fully portable Gas Chromatographic system equipped with the Option 06 Electron Capture Detection System. This system was fitted with a 6 foot 3% SE 30 on 80 - 100 mesh Chromosorb W HP column, which was maintained at 220°C. The carrier gas was Argon with 5% methane (P-5 gas) and its flow was maintained at approximately 40 ml/min. The output

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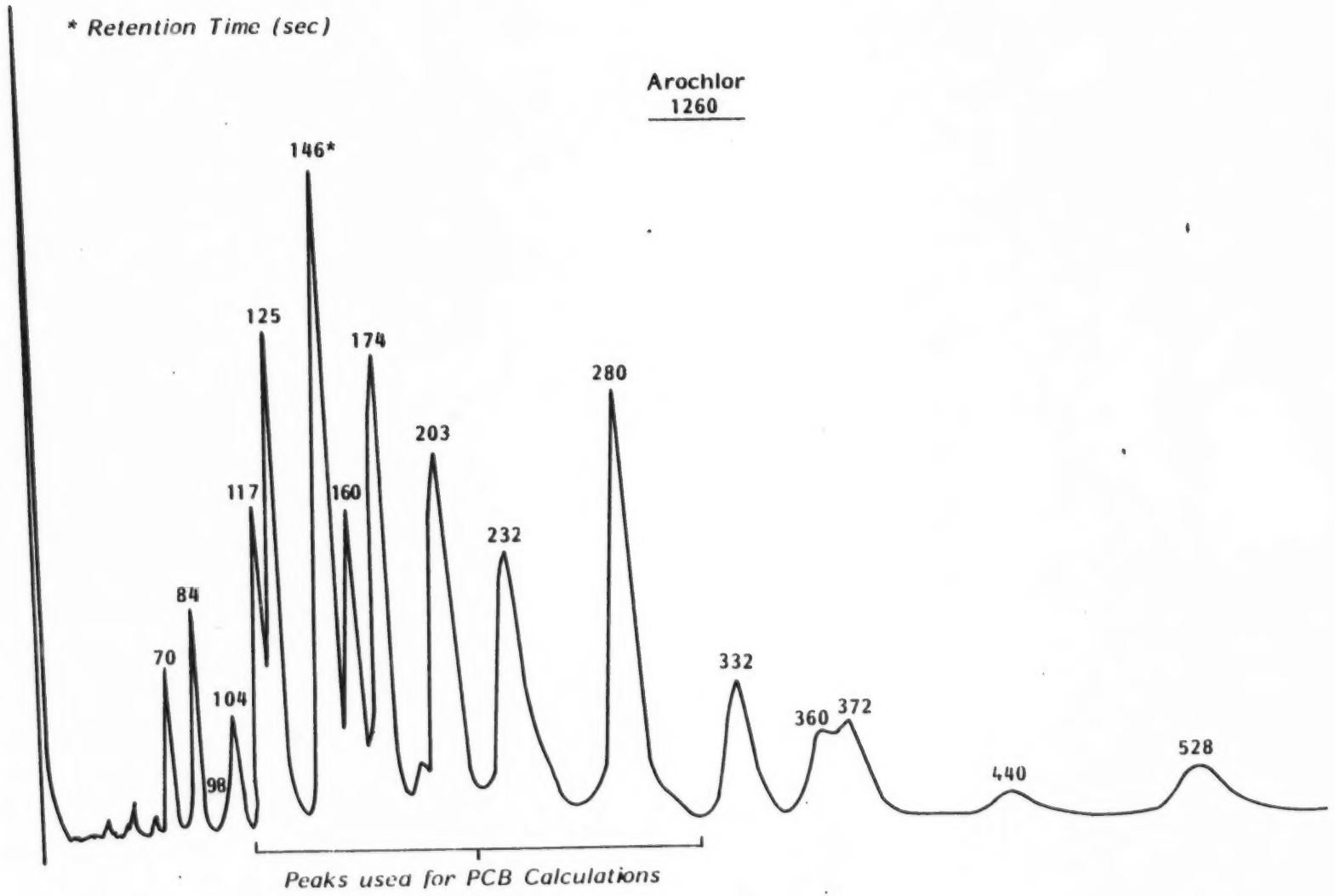
5 Whatman #1 filter paper.



170134 RD

FIGURE 11

TYPICAL CHROMATOGRAM SHOWING THE PEAKS USED FOR PCB CALCULATIONS

signal of the gas chromatograph was boosted by an operational amplifier and presented on a 50 mv strip chart recorder.

Input and output attenuation settings were 1 and 16, respectively, and quantitation of PCB was by peak height.

A5.3 Quality Assurance

Separate, 50 mg/kg Aroclor 1260, Aroclor 1254 and Aroclor 1242 standards in new Voltesso 35 insulating oil were prepared. These stock standards were kept on board the MPU-1 in 60 mL glass bottles sealed with liner-less plastic caps. Aliquots of the stock standards were diluted as described in Section A5.1 above, to produce injection standards, which were also stored on board the MPU-1.

An injection standard was always the first GC run of a day as a check on GC operation. Replicate analysis of oil samples by on-board GC, and the automatic capillary gas chromatograph GC of the Analytic Services Section, yielded the precision data presented in Table 22.

TABLE 22

PRECISION COMPARISON - ON BOARD GC AND AUTOMATED CAPILLARY GC[6]

Sample Number	PCB Concentration (mg/kg)		Standard Deviation (mg/kg)	Number of Analyses
	Capillary °C	On-Board GC (Avg)		
1	<2	<2	0	4
2	10	12.5	3	2
3	95	80	10	2
4	110	120	10	2
5	450	460	10	4
6	600	610	10	4
7	700	700	20	2
8	750	750	20	2
9	5000	5900	-	1

The data indicate relatively good precision for concentrations up to 750 mg/kg PCB and poor precision at 5000 mg/kg PCB. Because of this, oil samples of highly contaminated material (>1000 mg/kg PCB) were analysed by capillary gas chromatography.

[6] Capillary G.C. data is assumed exact - the precision of the capillary systems was previously determined to be 3.5-0.6% relative standard deviation.

A5.4 Water Quench of Oil Samples

Water addition to oil samples prior to PCB analysis was investigated as an alternative to hot filtering as a sample preparation method. Potential advantages include the quenching of residual sodium in the sample and removal of substances which might interfere in the analysis. A comparison of PCB results for oil samples filtered as described in A4.1 and identical samples to which 10 mL of water were added prior to filtering is presented in Table 23.

For samples 1, 2, 3 and 5 the two sets of results agree to within experimental error. However, for samples 4 and 6 the water addition method yields considerably lower PCB results. This is not unexpected based on the results of section 3.1.6, where it was noted that inhibition of the sodium/PCB reaction was overcome by the addition of water. Because of the above, hot filtering was the preferred pre-analysis treatment method, there being less chance of too low an estimate of oil PCB content.

TABLE 23

PCB ANALYSIS COMPARISON - HOT FILTERING VERSUS WATER ADDITION PLUS FILTERING

Sample Number	PCB Content (mg/kg)	
	Hot Filtered Sample	Sample With Water Added Prior to Filtering*
1	<2	<2
2	5	<2
3	15	15
4	55	5
5	65	75
6	350	250

* Approximately 10 mL water added to 30 mL oil.

Further study of sample pre-treatment will be required in field operations, especially if long delays between sample collection and analysis are expected.

APPENDIX 6

LEACHATE TEST PROCEDURE

This test was adapted from the Ontario Ministry of the Environment Leachate Extraction Procedure described in reference 5.

It consists of the following:

(1) Separate free liquid and solids from a 100 g sample.

(2) Extract 50 g of the solids portion with 800 mL of water for 24 hours.

(3) Titrate the aqueous layer to pH=5 after 1 h, 3 h, 6 h and 24 h of extraction, then make the leachate volume up to 1L.

(4) Analyse the aqueous portion for contaminants.

Liquid/solids separation (step 1) was performed by centrifugation at high speed for 4 h rather than the recommended pressure filtering to overcome filter blockage problems. The liquid phase (oil) was removed from the centrifuge tubes by syringe.

Step 2 was performed using a 2L glass beaker and a retort mounted high speed impeller system.

One normal HCℓ rather than the recommended acetic acid was used to neutralize the leachate to avoid introducing foreign ions (acetate) into the system and perhaps affecting subsequent analyses.

Prior to extraction neither centrifuge residue not Fuller's earth samples required subdivision as the residue was a smooth paste and the Fuller's earth particles quickly broke down into clay fines when mixed with water.

APPENDIX 7

GAS SAMPLER DATA PROCESSING

The PCB mass and average concentration data of Table 9 were calculated from the data from columns 2-5 of Table 24 below. For example, Gas samplers 1 and 6 were operating during processing of 2 batches at 50 mg PCB/kg. The batch size was 1250 kg, therefore the quantity of PCB destroyed during sampling was : $2 \times 50 \text{ mg/kg} \times 1250 \text{ kg} \times 10^{-6} \text{ kg/mg} = 0.13 \text{ kg}$

The average concentration was:

$$(50 \text{ mg/kg} + 50 \text{ mg/kg})/2 = 50 \text{ mg/kg}$$

The corresponding data for the remaining samplers were calculated similarly.

TABLE 24

BATCHES PROCESSED AND PCB DESTROYED WHILE GAS SAMPLERS OPERATING

Sampler* Number	Number of 1250 kg Batches Processed While Operating (By PCB Content - mg/kg)				PCB Destroyed While Sampler Operating	
	50	120	700	7000	Mass (kg)	Average Concentration (mg/kg)
1	2	-	-	-	0.13	50
2	2	-	2	-	1.88	375
3	-	2	3	-	2.93	468
4	-	3	-	-	0.45	120
5	-	-	7	2	23.63	2100
6	2	-	-	-	0.13	50
7	2	-	2	-	1.88	375
8	-	2	3	-	3.38	338
9	-	-	7	2	23.63	2100
10	1	1	1	1	9.84	1968
11	-	5	9	2	26.13	1239
12	-	5	9	2	26.13	1239

* Samplers 1 to 5 and 11 were located prior to the exhaust system carbon filters, samplers 6 to 9 and 12 were located after the carbon filters. Sampler 10 was located inside the trailer.

Average contaminant concentrations in the nitrogen cover gas prior to and after carbon filtering were calculated from the data from columns 3 to 5 of Table 25 below. For example, gas samplers 1 to 5 accumulated PCB from a point prior to the carbon filter. The total number of batches processed during sampling was:

$$2 + 4 + 5 + 3 + 9 = 23 \text{ (from column 3)}$$

Therefore, the weighed, per-batch average PCB concentration prior to carbon filtering was:

$$\frac{1}{23} \times (2 \times 335 + 4 \times 594 + 5 \times 961 + 3 \times 679 + 9 \times 1661) = 1080,$$

in milligrams PCB per kilogram oil.

The corresponding data for the remaining samplers and contaminant was calculated similarly.

TABLE 25

BATCH-WEIGHED AVERAGE CONTAMINANT CONCENTRATION IN NITROGEN COVER GAS

Sampler Number	Number of Batches Processed While Operating (From Table 24)	Cover Gas Contaminant Concentration (ng/m^3)			Batch-Weighted Average Cover Gas Contaminant Concentration (ng/m^3)
		PCB	T/TCB	Chloro-phenol	
1	2	335	21	<200	Samplers 1-5:
2	4	594	91	<100	PCB = 1080
3	5	961	844	<80	T/TCB = 2683
4	3	679	84	<190	Chlorophenol =
5	9	1661	6314	<50	<97
6	2	<24[1]	<12[3]	<200	Samplers 6-9:
7	4	<43[1]	<22[3]	<100	PCB = <133
8	5	152	76	<80	T/TCB = <124
9	9	186	220	<50	Chlorophenol = <83
10	4	<106[1]	53	<100	Sampler 10: PCB = <106 T/TCB = 53 Chlorophenol = <100

APPENDIX 8

FIRE PROTECTION SYSTEM TEST RESULTS

This Appendix contains:

(1) Research report C85-1-K, "Purging Test in the PCB Removal Trailer", by S. Chilakos.

(2) Levitt Safety Co. Discharge Report No 5662.

APPENDIX 8 - (1)

ontario hydro
research division

To Dr. R.W. Glass
Supervising Chemist
Organic Research Section
Chemical Research Department

PURGING TEST IN THE PCB REMOVAL TRAILER

S. Chilakos

Currently Ontario Hydro has in storage large quantities of PCB contaminated insulating oils. The high storage costs and inherent environmental hazards necessitated the Corporation to develop a process, utilizing sodium, to destroy the PCBs and recycle the insulating oil. This process is housed in a mobile unit and to maximize safe operation an argon gas release system was installed, which, when activated purges the sodium processing area and displaces the ambient air.

This study was designed to monitor the CO_2 concentration in the sodium processing area during Argon release to define the effectiveness of purging. This work was requested by the Organic Research Section.

Experimental Procedure

The apparatus used for the monitoring of CO_2 concentration is shown in Figure 1.

A Beckman Model 864 CO_2 Infra Red Analyzer was used to monitor the CO_2 concentration in the sodium processing room. The calibration data for the IR analyzer is summarized in Table 1. (A Millipore pump was used to provide a sample flow of 1.3 L/min and by using a three-way valve the CO_2 concentrations were measured at two locations (A and B, see Figure 2) at intervals of three minutes.)

Position A was 12.7 cm below the Argon Release Nozzle whereas position B was located 91.44 cm above the Nozzle.

Results

Results for the monitoring of CO_2 concentration in the sodium processing room are summarized in Table 2.

job	file	date	report no.
740632-185-090	837.341	March 18, 1985	C85-1-K

Figure 4 shows the CO_2 concentration vs time during and after the Argon release. The CO_2 concentration was reduced from 460 µL/L to 42 µL/L during the Argon release (0-7.25 minutes). Immediately after the Argon release the CO_2 concentration increased. In position A it was increased by 9.6 µL/L/min whereas in position B the CO_2 concentration increased at different rates. At the beginning (t = 9 min to t = 12 min) the rate was 19.5 µL/L/min and at the end (t = 20 min to t = 27 min) the rate was 7.6 µL/L/min.

In positions A and B the concentration of CO_2 reached 300 and 250 µL/L respectively 20 minutes after the argon release stopped.

Approved:

D.J.R. Dodd
Supervising Engineer
Environmental and Inorganic
Research Section
Chemical Research Department

Submitted:

S.G. Chilakos
Technician
Environmental and Inorganic
Research Section

SGC:kw

TABLE 1

CALIBRATION DATA OF IR BECKMAN CO_2 ANALYZER

Concentration of CO µL/L	IR Reading
19.3	5.0
23.4	6.0
35.0	8.0
46.8	10.0
58.6	12.0
117.1	21.5
234.0	37.5
351.3	50.0
468.4	60.0
585.5	69.0

TABLE 3

CONCENTRATION OF CO_2 RESULTS

IR Readings			CO_2 Conc
Time (min)	Sample A	Sample B	µL/L
0	58.5		460
1	43.9		290
2	33.0		200
3	24.0		135
4	-	18.0	84
5	-	13.5	66
6	-	10.0	48
7	9.0		42
8	10.0		48
9	12.8		63
10	-	15.0	76
11		18.0	94
12		24.0	135
13	20.0		106
14	20.8		112
15	22.8		126
16		33.8	206
17		34.8	214
18		36.5	228
19	28.0		164
20	29.5		175
21	32.0		185
22		41.0	264
23		42.0	274
24		43.0	282
25	35.5		220
26	37.5		234
27	39.0		248
28		46.0	310
29		46.5	314
30		46.5	314

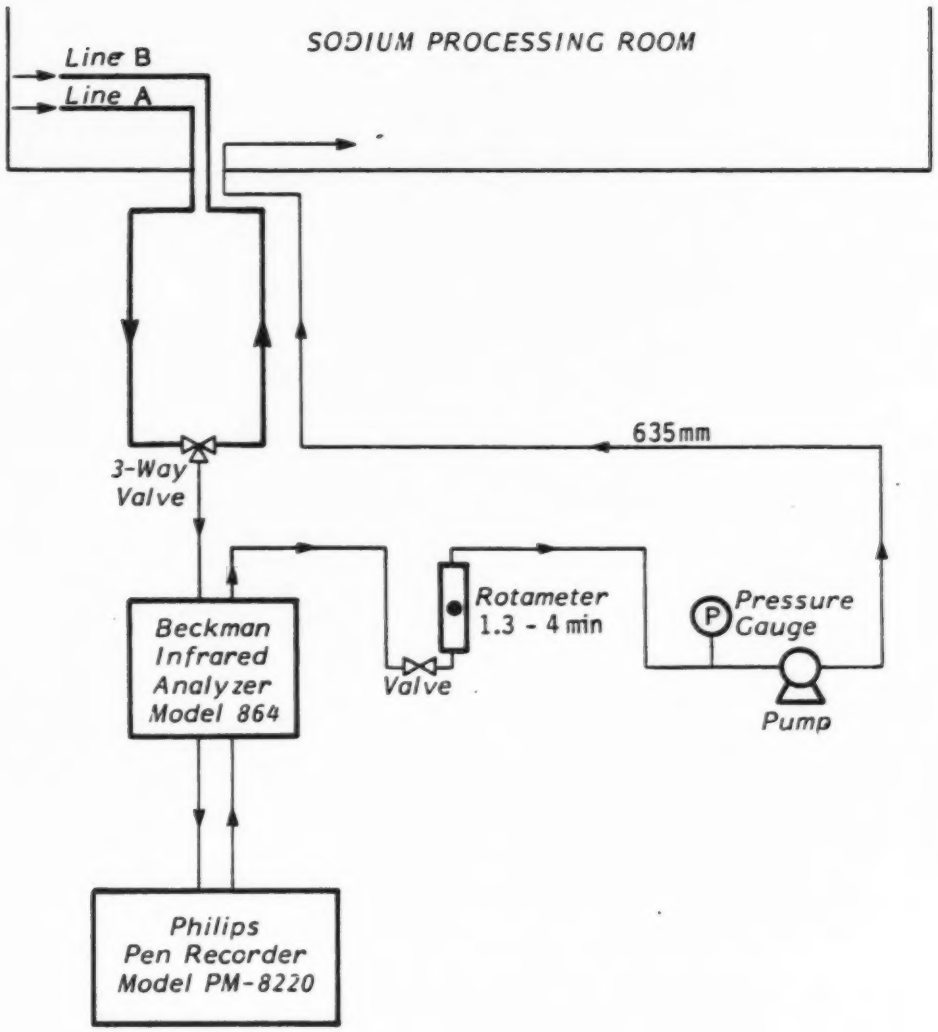


FIGURE 1

SCHEMATIC REPRESENTATION OF
EXPERIMENTAL APPARATUS

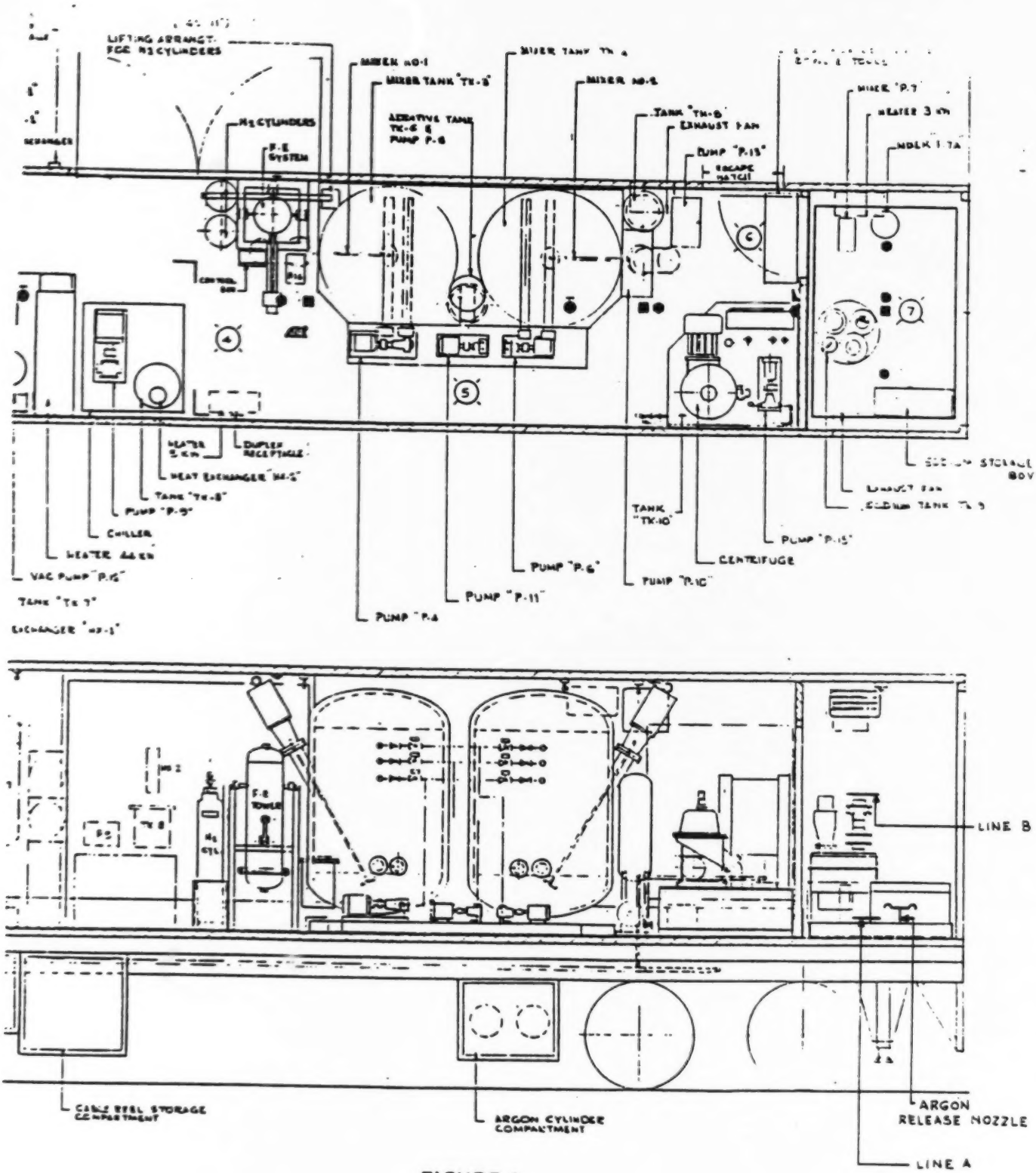


FIGURE 2

PCB REMOVAL TRAILER
SECTIONAL ELEVATION ON "A-A"

167660 RD

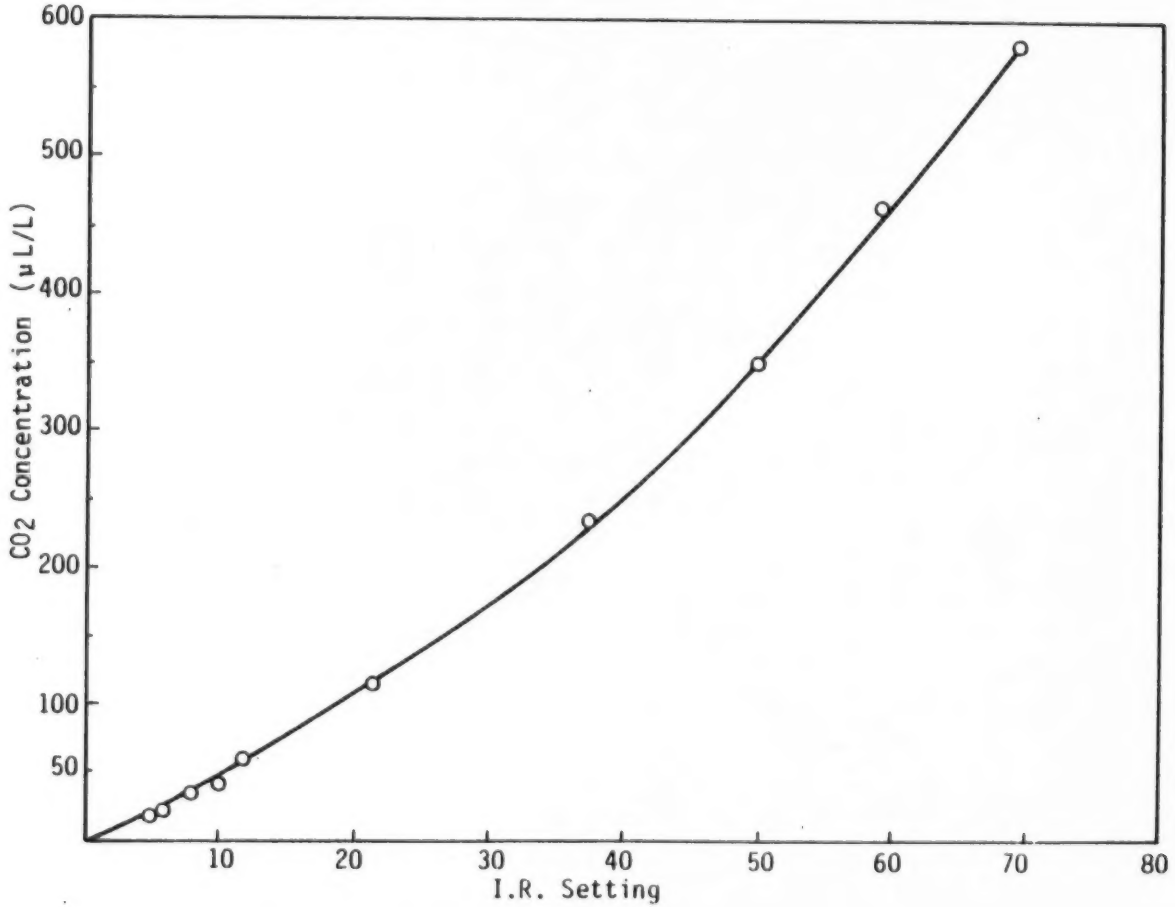


FIGURE 3

CALIBRATION CURVE FOR CO_2 CONCENTRATION

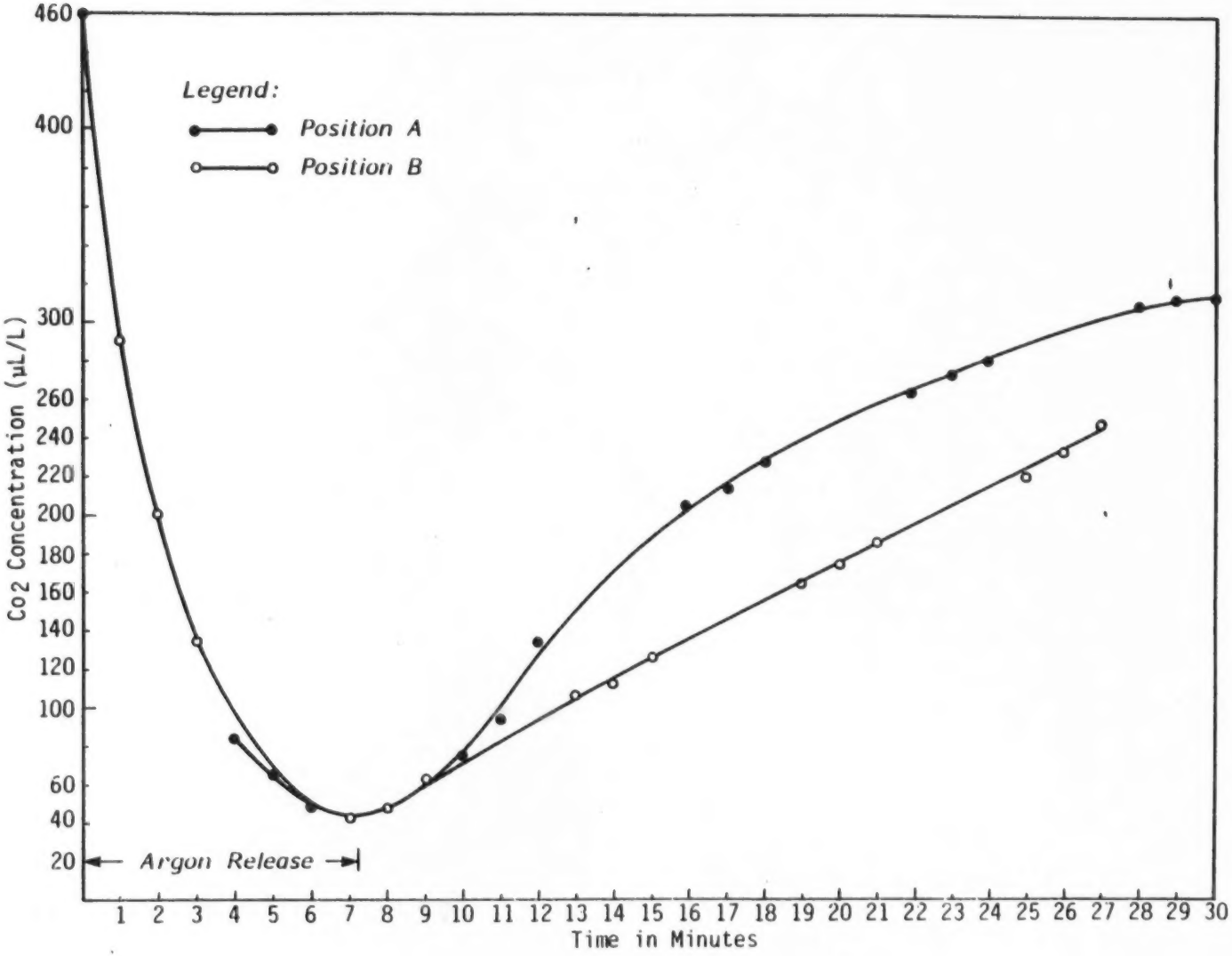


FIGURE 4

CONCENTRATION OF CO_2 VS TIME

APPENDIX 8 - (2) REPORT FROM LEVITT SAFETY COMPANY

DISCHARGE TEST NO. 5662

DATE: August 17, 1984 TEST TIME: 24:00

SYSTEM INSTALLATION: Enervac - Cambridge

APPLICATION: Ontario Hydro P.C.B. Trailer

TESTING AGENT: R122

CONTAINERS DISCHARGED:	LBS. / CONTAINER
1	62

SUMMARY OF EVENTS	TIME (MINUTES : SECONDS)
Start Discharge	00:00
Discharge Completed	00:12
End of Test	24:00

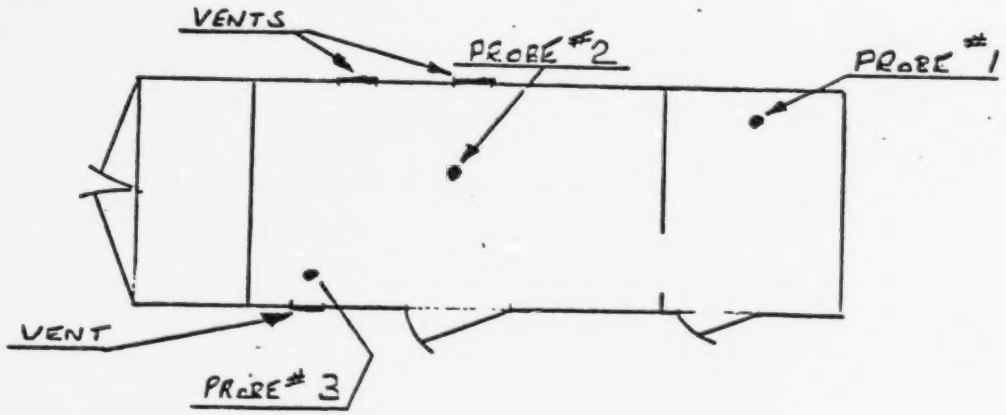
SUMMARY OF AGENT CONCENTRATIONS:

	SAMPLE POINT NO. 1	SAMPLE POINT NO. 2	SAMPLE POINT NO. 3
Concentration Volume %	10	9	8-1/2

TEST NUMBER 5662

ATTENDANCE	AFFILIATION
Ed Mewett	Ontario Hydro
James Ferrie -	Ontario Hydro
J. Greenfield	Ontario Hydro
John Janis	Ontario Hydro
Dave Bray	Ontario Hydro
Kerry Stan	Ontario Hydro
R.S. Mani	Enervac
Y.B. Mehtk	Enervac
Des Todd	Levitt-Safety

COMMENTS:



1) Leakage from the three vents caused the rapid reduction of concentration from the upper level - Probe #3 and also caused the reduction (although much slower) from the mid height Probe #2.

2) The higher than designed concentration is a result of reduced overall volume due to the solid objects present in the trailer.

3) Positive vent closing and sealing will improve greatly the ability of the trailer to maintain acceptable upper level concentrations.

SAMPLE POINT LOCATIONS:

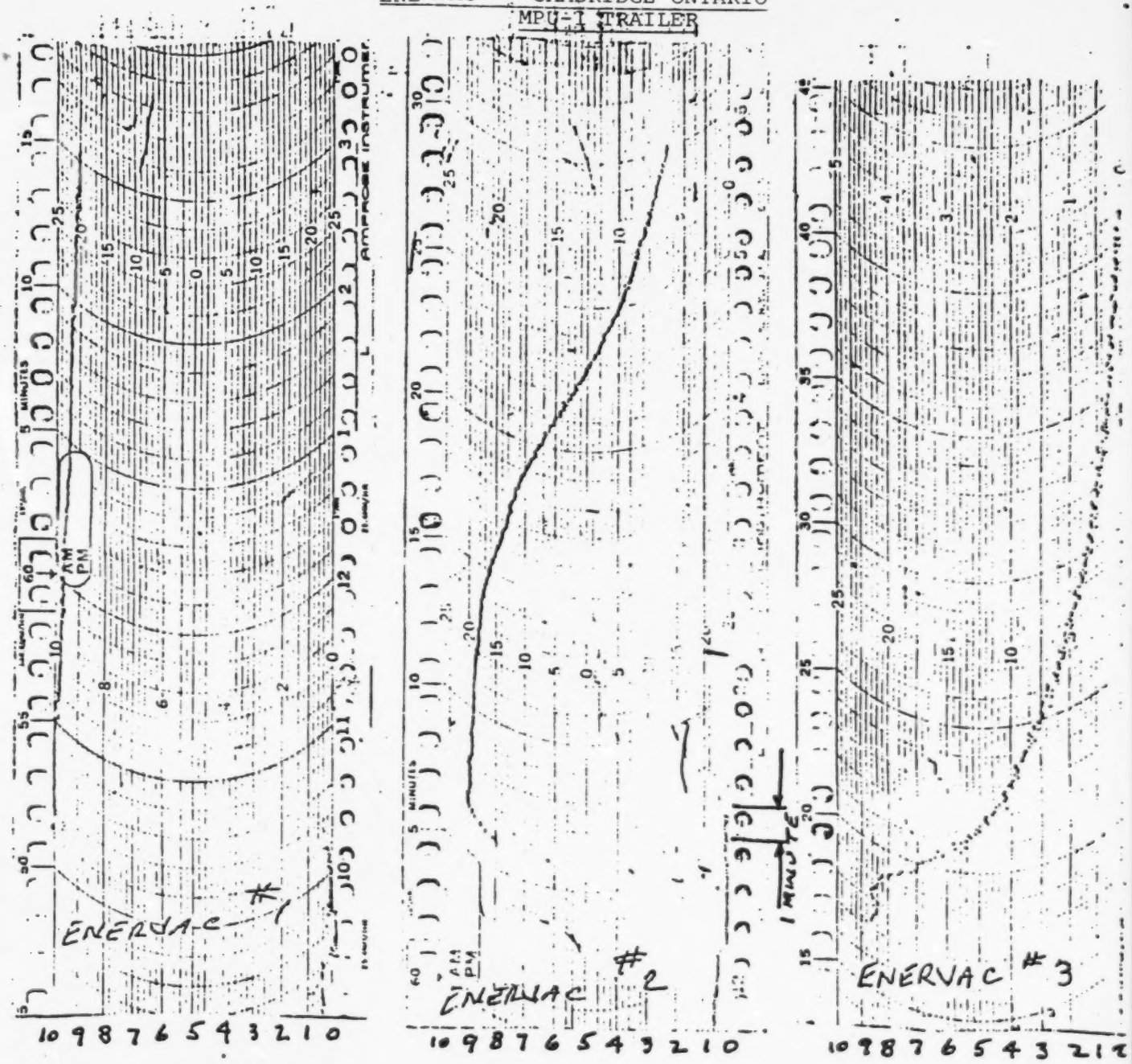
Point No. 1 - 12" from Floor Level

Point No. 2 - 4'-6" from Floor Level

Point No. 3 - 6'-6" from Floor Level

ENERVAC - CAMBRIDGE ONTARIO

MPU-1 TRAILER



LEVITT

CERTIFICATE OF INSPECTION

AUTOMATIC DETECTION AND OR FIRE SUPRESSION SYSTEM

COMPANY NAME: TORONTO HYDRO

ADDRESS:

HAZARD BEING PROTECTED: P.C.B. TRAILER

TYPE OF SYSTEM: HALON 1301 & ARGON

THIS SYSTEM HAS BEEN INSPECTED IN ACCORDANCE WITH THE MANUFACTURERS RECOMMENDATIONS.

AT THE TIME OF THIS INSPECTION, THE SYSTEM WAS IN FULL OPERATIONAL STATUS AND FUNCTIONED IN ACCORDANCE WITH THE DESIGN SPECIFICATION. THIS INSPECTION WAS CARRIED OUT ON AUGUST 17, 1984

RE INSPECTION DATE ON OR BEFORE: FEBRUARY 1985

INSPECTED BY: LEVITT-SAFETY LIMITED 33 LAIRD DR., TORONTO, ONTARIO M4G 3S9

INSPECTION CARRIED OUT BY: DES TODD

OWNER'S REPRESENTATIVE: J. GREENFIELD

SIGNATURE

(- 4 -)
- 64 -

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